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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF SOILS—MILTON WHITNEY, Chief.

IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA AGRICULTURAL EXPERIMENT STATION, THOMAS F. HUNT, DIRECTOR; CHARLES F. SHAW, IN CHARGE SOIL SURVEY.

RECONNOISSANCE SOIL SURVEY OF THE MIDDLE SAN JOAQUIN VALLEY, CALIFORNIA.

BY

L. C. HOLMES, IN CHARGE, AND E. C. ECKMANN, OF THE U. S. DEPARTMENT OF AGRICULTURE, AND J. W. NELSON AND J. E. GUERNSEY, OF THE UNIVERSITY OF CALIFORNIA.

MACY H. LAPHAM, INSPECTOR, WESTERN DIVISION.

[Advance Sheets—Field Operations of the Bureau of Soils, 1916.]

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF SOILS,
Washington, D. C., May 31, 1918.

SIR: I have the honor to transmit herewith the manuscript report and map covering the reconnoissance soil survey of the Middle San Joaquin Valley, California, and to recommend that they be published as advance sheets of Field Operations of the Bureau of Soils, 1916, as authorized by law. This work was done in cooperation with the University of California.

Respectfully,

MILTON WHITNEY,
Chief of Bureau.

Hon. D. F. HOUSTON,
Secretary of Agriculture.

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RECONNOISSANCE SOIL SURVEY OF THE MIDDLE SAN JOAQUIN VALLEY, CALIFORNIA.

By L. C. HOLMES, In Charge, and E. C. ECKMANN, of the United States Department of Agriculture, and J. W. NELSON and J. E. GUERNSEY, of the University of California.—Area Inspected by MACY H. LAPHAM.

DESCRIPTION OF THE AREA.

GEOGRAPHY.

The reconnoissance soil survey of the Middle San Joaquin Valley, California, covers a section extending east and west across the central part of the San Joaquin Valley and embracing about one-third of its total area. The survey lies near the geographical center of the State. Fresno, the principal city, is 206 miles from San Francisco and 278 miles from Los Angeles by way of one of the main rail lines. The western boundary of the area is about 55 miles inland from the Pacific Ocean and the eastern part about 90 miles from the California-Nevada State boundary. The area is bounded on the north by latitude 36° 50′ from the northwestern corner to the point at which this line intersects the San Joaquin River, a distance of about 22 miles. From this point the boundary follows the meandering course of this stream almost to the northeastern corner of the area. The southern bounday lies along latitude 36°. The survey is bounded on both the east and west by irregular lines located for the most part so as to include narrow belts of the lower foot slopes of the Sierra Nevada and Coast Range Mountains, respectively, the general trend of both boundaries being northwest to southeast. The form of the area is roughly that of a parallelogram averaging a little less than 60 miles from north to south and a little less than 75 miles from east to west.

FIG. 1.—Sketch map showing location of the Middle San Joaquin Valley area, California.

The survey covers 4,448 square miles, or 2,846,720 acres, and comprises parts of Fresno, Tulare, and Kings Counties. Of the total area of the survey, about 2,519 square miles is in Fresno County, about 1,162 square miles in Tulare County, and about 587 square miles in Kings County. A little less than one-half of Fresno County, less

than one-fourth of Tulare County, and about one-half of Kings County are included. The main agricultural development and centers of settlement and industry of each county are included in the area, and with the exception of a few important but local sections the remaining parts of the counties are largely mountainous or sparsely settled.

The base for the soil map accompanying this report is compiled from several sources. For the western part of the area topographic sheets of the United States Geological Survey are used, some changes in culture being made to bring the information up to date. For the eastern and east-central parts detailed soil surveys of the Fresno and Hanford areas and a part of that of the Porterville area are used.[1]

The base maps of the earlier Fresno and Porterville areas are used with some additions and changes, but without attempting to show all recent changes in location of roads and buildings. The remainder of the map was constructed in the field, the work being aided and verified in part by county and city maps.

The survey covers an important part of the Great Interior Valley of California, one of the most prominent physiographic divisions of the State. This valley is an elongated trough of northwest-southeast trend which parallels the eastern and western boundaries of the State, but lies a little nearer the Pacific Ocean than the eastern boundary. It extends from Redding on the north to beyond Bakersfield on the south, a distance of about 500 miles. Its average width is about 40 to 45 miles and the northern and southern extremities of the main valley near Red Bluff and Bakersfield are rounded rather than tapering. The valley is inclosed by mountain ranges except for a break on the west side a little north of its center where drainage waters have their outlet to the Pacific Ocean through intermediate bays. To the east is the Sierra Nevada Mountain range which attains near its southern part maximum elevations of over 14,000 feet, and is drained into the valley by numerous rivers. The Coast Range Mountains lie to the west. They are made up of several parallel ranges of lower elevation than the Sierra Mountains, and contribute much smaller quantities of run-off to the valley. The generally parallel mountain ranges on the east and west merge around the north and south ends of the valley by means of connecting ranges. The boundary between the valley and the mountains usually is sharp, especially along the western side.

The Great Interior Valley is commonly considered as being composed of two valleys. The northern and smaller part lying north

[1] Soil Survey of the Fresno Area, California, Field Operations of the Bureau of Soils, 1912; Soil Survey of the Hanford Area, California, Field Operations of the Bureau of Soils, 1901; Soil Survey of the Porterville Area, California, Field Operations of the Bureau of Soils, 1908.

of the drainage outlet through the Coast Range is known as the Sacramento Valley[1] and the southern part as the San Joaquin Valley.[2]

The northern valley is drained by the Sacramento River, and the southern valley by the San Joaquin River. These two main streams join west of Stockton near their outlet through a low-lying section known as the Island Region. The great interior trough or basin is a unit, and the Sacramento and San Joaquin Valleys are very similar and are parts of the same feature, differentiated by name only.

TOPOGRAPHY.

The section of the San Joaquin Valley included in this survey consists largely of smooth valley slopes which flatten toward the valley trough and steepen toward the mountain foot slopes. This somewhat monotonous topography is relieved near the eastern and western sides by the diversified foothill or mountainous areas. In addition a few outlying hills rise from the higher valley slopes and together with some rolling areas of intermediate character between the valley surface proper and the marginal mountainous parts constitute the most diversified portions of the area.

The streams usually enter the valley from canyonlike mountain valleys and flow through shallow valleys across the higher marginal belts of the valleys, but this condition frequently is reversed within a few miles as the streams emerge upon relatively elevated alluvial fans built across areas of lower gradient. The low axial trough of the valley has a very slight northward slope. It lies nearer the western side, leaving about two-thirds of the area on its eastern side. Its lower elevations average about 165 feet above sea level near Mendota, and at Wheatville, almost 30 miles southeast, a little over 200 feet. The trough of the valley is obstructed farther south by a low lobe of alluvium, the divide of which is about 210 feet in elevation. The basin on the south side of this lobe is occupied by Tulare Lake, about 115 square miles of which is included in the survey. The bottom of the lake has an elevation of about 180 feet, which gives a difference in elevation of only about 15 feet along the trough of the valley from near Mendota, or a distance of almost 60 miles.

The slopes of the eastern side of the valley are largely tillable and support most of the agricultural development of the area. They have a lower gradient than those of the west side and are longer. The eastern margin of the valley near the mountains ranges in ele-

[1] This valley is covered by a similar survey. Reconnoissance Soil Survey of the Sacramento Valley, California. Field Operations of the Bureau of Soils, 1913.

[2] The present survey is joined on the north by a prior survey covering the northern part of the San Joaquin Valley. Reconnoissance Soil Survey of the Lower San Joaquin Valley, California. Field Operations of the Bureau of Soils, 1915.

vation from about 350 to over 500 feet, gradually increasing southward, as indicated by elevations at Friant, Minkler, and Porterville, of 345, 407, and 460 feet, respectively. The included mountainous rim, or outlying hills, are largely nonagricultural, and often rises through rocky, abrupt slopes to elevations of several hundred feet above the valley margins. Sanger, with an elevation of 370 feet; Reedley, 349 feet; Exeter, 319 feet; and Lindsay, 385 feet, are located on the upper valley slopes at varying distances from the foothills. Elevations along the middle eastern valley slopes are 294 feet at Fresno, 218 feet at Kerman, 310 feet at Selma, 332 feet at Visalia, 289 feet at Tulare, and 246 feet at Hanford. The average fall of the east side to the trough of the valley is about 4 or 5 feet per mile, being several times this on some of the upper slopes and much less over the lower extensions.

The surface features of the alluvial valley slopes of both the east and west sides are the result almost entirely of stream activities, either past or present. The older alluvial deposits are fragmentary or extensive, depending upon the extent of reworking, erosion, or covering they have received. The older and younger materials are sometimes reversed in relative elevation, the more recent being relatively lower than the older on the upper valley slopes but higher farther out, where alluvial fans are now being built up by the streams, although such relations are subject to many exceptions. Sharp breaks in topography are rare, although the operations of the major streams have caused important variations. Chief among these are the broad recent alluvial fans of Kings, Kaweah, and Tule Rivers, which flatten valleyward and by extended lobes sometimes tend to surround older lower-lying areas.

The west side of the valley attains elevations of from 500 to 700 feet or more along its hill line, and in some instances has as much as 200 feet fall per mile for a short distance valleyward. Such exceptional gradients soon flatten to about 20 feet or less per mile and often to 5 or 10 feet as the trough of the valley is approached. Pleasant Valley, in which Coalinga is located, ranges in elevation from about 600 to 800 feet, and these higher valley elevations continue to the south through the Kettleman Plain, which lies behind a group of outstanding hills known as the Kettleman Hills. The included parts of the lower Coast Range are sharply rolling or choppy, reach elevations of 1,000 to 1,200 feet, and usually break into the valley along regular lines, except where indented by small valleys. Many tillable areas are included in these mountains which can not be utilized because of the low rainfall. The west side of the valley is a monotonously uniform, sloping plain, dominated almost entirely by coalescing recent alluvial fans. A few remnants of slightly higher, older

fans, and outlying hills lie along its upper margin and there are local fans that vary in size or height. This side of the valley is almost wholly tillable, but is little used for agriculture.

DRAINAGE.

The Sierra Nevada Mountains to the east are the source of several important streams entering the area, chief among which are the San Joaquin, Kings, Kaweah, and Tule Rivers. The streams in most instances flow down the valley slopes at about right angles to the axis of the valley, but their outlets and their relation to drainage vary. The San Joaquin River has its source in the high Sierra Nevada Mountains to the northeast of the area, where it drains a considerable area of mountainous land above Friant.[1] As with the other major streams of the east side of the valley, its maximum flow accompanies the melting of the snow during the late spring and early summer periods, this being succeeded by a minimum flow preceding the winter rains. This stream forms the boundary of the area surveyed from near its northeastern corner to the trough of the valley, but here swings from a southwest to northwest direction and, proceeding along the trough, constitutes the principal drainage way of the San Joaquin Valley as a whole. It is flanked in its upper course by a narrow belt of bottom land, but farther down the valley slope flows in a rather regular channel, which seems to be neither cutting nor filling at a rapid rate. At its elbowlike turn down the valley it is joined by Fresno Slough, or Tulare Lake Slough, as it is sometimes called, the only drainage outlet for the upper San Joaquin Valley. Aside from being an outlet for this slough, the San Joaquin River has little influence on the drainage or the present soil-forming processes of this survey. The Kings River enters the valley east of Fresno, near Centerville, draining about 1,740 square miles of the eastern part. It flows in several channels through a well-defined bottom for a short distance, and these give way to a single channel slightly below the surrounding lands. This channel divides again farther down the valley slopes, and the stream traverses an alluvial fan through bifurcating and oftentimes poorly defined channels. The Kaweah River enters the area near Lemoncove and drains about 520 square miles of mountainous land, nearly all of which lies to the east of the survey. The stream divides almost immediately into two distributaries, the northern being known as the St. Johns River. From this point southwestward the channels irregularly subdivide or reunite across an extensive alluvial fan, becoming more indistinct and spreading valleyward, the northern ones passing north of Goshen and the southern ones south of

[1] Water Supply Paper No. 398, Ground Water in San Joaquin Valley, California, and Water Supply Paper No. 299, Water Resources of California, Part II, Stream Measurements in San Joaquin Basin, U. S. Geol. Survey.

Tulare. This fan is traversed by the line of the Southern Pacific Railroad for more than 20 miles. The Tule River emerges from the mountains east of Porterville, having a drainage area above the latter place of about 266 square miles. Like the Kaweah, it has built an alluvial fan, which it traverses through dividing channels of discontinuous character, except for one or two shallow passages. There are in addition several minor streams on the east side of the area, such as Sand, Cottonwood, Yokohl, and Lewis Creeks, which drain the lower foothills and discharge into the valley.

All the streams mentioned on the east side, with the exception of the San Joaquin River, are without outlet to the sea during normal years. Their waters finally reach the trough of the valley by devious courses across regions of low gradient and collect in Tulare Lake, which fluctuates greatly in size. After a few wet years this sink fills and overflows to the north by way of Fresno Slough across the barrier built by the sedimentation from crowding fans. After a period of exceptionally dry years it becomes dry, as in 1905.

The Coast Range Mountains on the west yield only minor streams, such as Los Gatos, Waltham, Cantua, and Panoche and Little Panoche Creeks. These are largely intermittent and, except during or immediately following the rainy season, their beds over the valley slopes are dry. The first two creeks, with their several tributaries, originate in the mountains west of Coalinga, but join near the outer foothills and, continuing northeastward, occupy a broad alluvial fan whose lower extension assists in partially blocking the trough of the valley. The last three creeks are similar in character and lie to the north in the order named. They drain extensive mountainous areas to the west. Owing to the low regional rainfall, they have a restricted but greatly fluctuating discharge. They have built large, symmetrical alluvial fans with some well-defined lobes which extend almost to the valley trough, their drainage reaching Fresno Slough or the San Joaquin River. Numerous minor washes intervene between the larger creeks, each with its local fan.

Drainage conditions vary widely in different parts of the area. Run-off is rapid on all the hilly or rolling lands, and with the exception of local swales the drainage is sufficient or excessive. The higher valley slopes of the east side are nearly always well drained, but some of the soils have obstructed subdrainage, so that they are boggy during and for short periods after the rainy reason. The west side of the valley has good drainage except in an irregular, flattened belt along the valley trough. The larger streams are sometimes bordered in their upper courses by flat lands which have a high-water table and are periodically overflowed. Nearly all the streams overflow a part of their fans for short periods in times of flood, but damage from overflow is relatively small as compared with that

occasioned by a high water table, the result of seepage from higher regions. As mentioned further on in the chapter on alkali, important low-lying areas have been seriously damaged by overburdening the subsurface drainage. The alkali soils, as shown on the soil map, approximately coincide with the areas of stagnated drainage. There are some defectively drained soils not badly affected by alkali, chiefly along Fresno Slough and around Tulare Lake, where overflow and leaching has been sufficiently frequent to offset the tendency toward accumulation.

POPULATION AND CITIES.

Fresno County was formed in 1856, Tulare County in 1852, and Kings County in 1893. The following table indicates the growth of the population of these counties, according to the census:

Population of Fresno, Tulare, and Kings Counties, 1880, 1890, 1900, and 1910.

Census year.	Fresno County.			Tulare County.[1]			Kings County.		
	Rural.	Urban.	Total.	Rural.	Urban.	Total.	Rural.	Urban.	Total.
1880	9,478	.....	9,478	11,281	.....	11,281	.....	.....	.....
1890	21,208	10,818	32,026	19,082	5,492	24,574	.....	.....	.....
1900	25,392	12,470	37,862	13,074	5,301	18,375	6,942	2,929	9,871
1910	46,566	29,091	75,657	25,436	10,004	35,440	11,401	4,829	16,230

[1] County reduced in size between 1890 and 1900.

The total population of the three counties in 1910 was 127,327, and it is estimated that the total for the portions of the counties included in this survey was about 118,200, indicating the sparsely settled character of the portions outside the area. Of this total for the area, about 72,000 are in the included part of Fresno County, about 31,000 in the Tulare County portion, and 15,200 in the Kings County portion. On this basis the part of Fresno County within the survey has an average population per square mile, including the urban population, of 28.58; Tulare County, 26.67; and Kings County, 25.89. The population of all the counties has increased substantially since 1910, the proportionate increase being perhaps as great as that of the decade from 1900 to 1910.

The inhabitants are largely native-born whites, this class constituting 73 per cent of the population of Fresno County, 85.3 per cent of that of Tulare County, and 77.5 per cent of that of Kings County. Foreign-born whites make up 21.1 per cent, 11.1 per cent, and 17.2 per cent of the population of these counties, respectively. The remainder is largely Chinese, Japanese, and Indian, negroes constituting a negligible percentage. Natives of Denmark, Germany, Italy, Russia, Sweden, and Turkey predominate in the foreign-born popu-

lation of Fresno County, those of Germany and Mexico in Tulare County, and of Portugal and Mexico in Kings County. More than one-half the total population of the survey is concentrated in the eastern third of the area. The central third is thickly populated, but the western third is very sparsely settled, Mendota, Tranquillity, Huron, and the oil-producing region around Coalinga being practically the only centers.

Fresno, the county seat of Fresno County, is the largest city in the San Joaquin Valley and the principal business center for an extensive region. It is the center of the raisin industry of the country. It has gained in population from 1,112 in 1880 to 24,892 in 1910. Visalia, the county seat of Tulare County, is one of the older towns, and is located in a fruit and general-farming region. It had a population of 2,885 in 1890 and 4,550 in 1910. Hanford, the county seat of Kings County, is located nearer the center of the valley than any other place of equal importance and is surrounded by deciduous fruit, dairying, and general-farming industries. It had 942 inhabitants in 1890 and 4,829 in 1910. The three county seats were the largest cities of the area in 1910. Porterville, in the southeastern part of the area, with 2,696 inhabitants in 1910; Lindsay, farther north, with 1,814 inhabitants; and Strathmore and Exeter are located near the foothills and are important centers in the citrus-fruit belt of Tulare County. Other towns in Tulare County are Tulare, with 2,758, and Dinuba, with 970, inhabitants in 1910; Sultana, Orosi, Cutler, Tipton, and Goshen. Other towns of local importance in Kings County are Armona, Lemoore, Corcoran, and Stratford. Fowler, Selma, Kingsburg, Reedley, Sanger, Kerman, Clovis, Laton, Mendota, and Coalinga are in Fresno County, the last two being on the west side of the valley. Coalinga had 4,199 population in 1910 and is the center of one of the most important oil-producing regions of the State, the production in 1912 from this section amounting to 19,911,820 barrels, valued at $8,768,303. There are numerous small towns and shipping points throughout the survey in addition to those named.

TRANSPORTATION.

Main and branch lines of the Southern Pacific and of the Atchison, Topeka & Santa Fe Railroads furnish the principal rail transportation of the area. The main San Joaquin Valley line of the Southern Pacific lies midway between the valley trough and the eastern edge of the valley. It divides at Fresno, one line crossing the valley to the west through Kerman and Mendota, where it leaves the area to the northwest, while the other line continues from Fresno northwestward along the east side of the valley. These two lines reunite at Tracy, in the lower portion of the valley. Another line

of the Southern Pacific leaves the main line at Fresno and runs southeastward along the higher valley slopes through Sanger, Reedley, Exeter, and Porterville, rejoining the main line at Famose, south of the area. From Goshen Junction, on the main line of the Southern Pacific, branches run east through Visalia to Exeter and west across the valley to Coalinga. A branch from the latter line at Armona runs northwest to Kerman. There are other branch lines of the Southern Pacific, as from Fresno northeast to Friant and east from Porterville.

The transcontinental line of the Atchison, Topeka & Santa Fe Railroad lies west of the Southern Pacific main line in the southern part of the area, but crosses to the east at Fresno. From Corcoran a branch runs northeast through Tulare, Visalia, Cutler, Dinuba, and Reedley and rejoins the main line at Fresno. A branch runs north from Reedley to Minkler, and from the latter place a newly constructed line, known as the Minkler & Southern, runs southeastward through the citrus-fruit belt to Porterville. The Laton & Western Railroad, affiliated with the Santa Fe, serves an area west of Laton, in the middle of the valley. The Hanford & Summit Lake Railroad affords transportation to some of the low-lying region in the trough of the valley. The Visalia Electric Railroad operates lines connecting Visalia, Exeter, Lemoncove, and Woodlake, and is now engaged in further construction. Suburban electric lines run from Fresno to Clovis and northward from Fresno. Most of the developed regions are well supplied with transportation facilities, but much of the west side of the valley is without rail lines.

The highways of the area vary greatly in character, the thickly settled regions being well supplied with good roads and the sparsely settled sections, such as the west side, being practically without improved roads. A main line of the State highway system parallels the Southern Pacific Railroad throughout the area and is now improved as far south as Goshen Junction, with branches east and west to Visalia and Hanford. It is planned to continue construction on this trunk line to the south to connect with completed sections toward Los Angeles, while another branch is planned across the Coast Range Mountains to connect with the State highway along the coast. Kings County is building an extensive system of permanent highways, and the tendency throughout the area is toward highways of expensive and durable construction. Main roads are well graded and oiled. Automobile stage and express lines connect practically all the towns, being run on established schedules and at rates which compete with railroad tariffs.

The specialized agricultural products of the area, including dried and canned fruits, raisins, and wines, the citrus fruits, and to a

less degree table grapes and fresh fruits, constitute a large part of the income products of the area and are widely distributed throughout the country. Hay, dairy and meat products, and most of the more bulky or perishable products are marketed or consumed within the area or are shipped to less distant markets than fruit.

Telephones are in common use throughout the rural regions. Electricity is furnished for home use and for pumping for irrigation by a network of lines radiating from power plants located along the rivers in the mountains to the east.

CLIMATE.

GENERAL CONDITIONS.

The climate of the Middle San Joaquin Valley area is typical of that of interior California. The year is divided into two seasons which contrast in precipitation and humidity as well as in temperature. The summer, or dry season, comprises the late spring, summer, and early fall months, extending approximately from May to September inclusive. Measurable rainfall is often lacking for several months during this season, and an average of less than one-half inch falls from June to September inclusive. Temperatures average high during this season, with readings of 100° to 110° F. or more not unusual in midsummer, the extreme heat being alleviated somewhat by a very low humidity. The winter, or wet season, includes the late fall, winter, and early spring months, extending from about October to April, in which time nearly all the normal rainfall occurs. During this period temperatures average lower and the relative humidity much higher, with frequent frosts and low temperatures ranging several degrees below freezing.

Conditions of temperature, precipitation, humidity, and wind movement vary somewhat from place to place in the area. Hot, dry summers contrasted with cool, wet winters are the rule throughout the San Joaquin and Sacramento Valleys, with minor local variations in climatic conditions that have a marked influence on agricultural practices. For the sun-dried fruit industries dry summer and early fall months are required, the citrus industry depends upon unusual freedom from frosts, and certain crops, such as English walnuts and lima beans, seem to require cooler localities of high relative humidity.

PRECIPITATION.

The following table gives the precipitation as recorded at four weather bureau stations within the area. The Fresno, Visalia, and Porterville stations are on the east side of the valley, the last named being near the foothills. The Mendota station is on the west side, but near the valley trough.

Mean monthly and annual precipitation, with amounts for driest and wettest years.

Month.	Fresno (1881–1911), elevation, 292 feet.			Visalia (1877–1911), elevation, 334 feet.		
	Mean.	Total amount for driest year (1910).	Total amount for wettest year (1884).	Mean.	Total amount for driest year (1910).	Total amount for wettest year (1884).
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
January	1.71	1.22	2.54	2.03	1.16	2.85
February	1.36	.21	4.35	1.54	.03	4.10
March	1.81	1.28	3.77	1.81	1.68	3.90
April	.97	.27	3.42	1.02	.22	3.45
May	.56	T.	1.43	.45	0	.30
June	.11	T.	1.25	.07	0	0
July	T.	T.	0	.01	0	0
August	T.	0	0	T.	0	0
September	.29	1.00	0	.29	.15	0
October	.63	.45	.46	.48	.15	.36
November	1.13	.24	.08	.82	0	0
December	1.47	.21	3.93	1.50	.71	4.63
Year	10.04	4.88	21.23	10.02	4.10	19.59

Mean monthly and annual precipitation, with amounts for driest and wettest years.

Month.	Porterville (1889–1911), elevation, 464 feet.			Mendota (1894–1908), elevation, 177 feet.		
	Mean.	Total amount for driest year (1898).	Total amount for wettest year (1906).	Mean.	Total amount for driest year (1897).	Total amount for wettest year (1906).
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
January	1.96	0.75	2.54	1.20	1.21	0.92
February	1.50	1.55	1.35	1.04	.67	1.37
March	1.92	.08	6.59	1.07	.86	3.40
April	.85	T.	2.20	.34	.07	.79
May	.63	.55	3.29	.37	0	.47
June	.10	0	.02	.03	T.	0
July	.03	0	0	.01	.13	0
August	.01	0	0	T.	0	0
September	.28	2.10	0	.13	0	T.
October	.50	T.	0	.45	.68	0
November	.72	.27	.30	.70	.22	.51
December	1.46	.35	3.80	.95	.08	3.02
Year	9.96	5.65	20.09	6.29	3.79	10.48

The precipitation is greatest along the foothills on the east side of the valley, and decreases gradually to the west and south, the west side of the valley receiving much less rain than the east side. The section of the valley covered by this survey has a lower rainfall than

the northern part, as indicated by the more northern stations at Stockton, Modesto, and Merced, on the east side, with average precipitations of 14.57, 11.32, and 10.82 inches, respectively, and at Tracy, Newman, and Los Banos, on the west side, with 10.37, 11.18, and 8.52 inches, respectively. The rainfall is higher, however, than in the upper part of the valley to the south where the mean annual precipitation at Bakersfield and Delano is recorded as 5.39 inches and 6.39 inches, respectively. Precipitations for other stations within the area are Lemoncove with 15.95, Reedley with 11.70, Sanger with 10.61, Selma with 9, Tulare with 8.17, and Hanford with 8.54 inches. These figures illustrate how the rainfall decreases to the south and west, and while complete figures are not available for the southwestern section of the area, the average is lower than for Mendota. There is considerable yearly variation in the rainfall, and its seasonal distribution also is variable, as most of the annual precipitation sometimes occurs within a short period.

The region is semiarid to arid, dry-farming being practically restricted to the production of hay and grain, except on some of the moist, low-lying subirrigated lands, on which some other crops can be grown without irrigation. Broad areas on the west side of the valley require irrigation, even for grain. Snow is rare, having fallen in appreciable amounts at Fresno only twice since the establishing of the local Weather Bureau office in 1887. Hail and thunderstorms also are infrequent.

TEMPERATURE.

The following table gives the mean monthly and annual and the maximum and minimum temperatures for several stations in the area:

Mean monthly and annual and maximum and minimum temperatures.

Month.	Fresno.			Visalia.			Porterville.		
	Mean.	Absolute maximum.	Absolute minimum.	Mean.	Absolute maximum.	Absolute minimum.	Mean.	Absolute maximum.	Absolute minimum.
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
January	45.4	73	17	45.6	80	13	48.0	83	18
February	49.2	83	24	50.3	86	21	51.8	85	25
March	54.9	87	28	52.5	85	22	56.2	88	31
April	61.2	101	34	58.3	104	26	62.9	101	32
May	68.4	110	38	66.1	107	35	70.3	109	38
June	75.8	112	42	73.3	108	35	78.8	111	40
July	82.0	115	50	80.0	114	44	84.8	114	44
August	81.2	113	51	78.4	110	40	82.6	114	50
September	74.3	111	42	71.7	110	35	75.1	112	41
October	64.7	100	36	63.1	98	27	64.9	102	35
November	54.6	84	27	53.6	89	24	54.9	95	26
December	46.8	74	23	46.2	86	20	47.8	85	22
Year	63.2	115	17	61.6	114	13	64.6	114	18

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range from about 61° to
lls on the east side of the
an annual temperature of
Tulare 63.8° F. each, and

nd warmer in summer than
mers are very hot and are
res gradually mount from
ral days of less than 100°.
ummer season to escape the
peratures for July, the hot-
erville are 99.7° F., 99.1° F.,
winter season often includes
r without temperatures ap-
n minimum temperatures for
erville are 37.5° F., 33.4° F.,
hest removed from the foot-
oldest. The daily range of
ummer, when it often amounts

to 40° or more.

FROSTS.

Frost and freezing temperatures vary sufficiently within the area to have affected the distribution of the fruit belts. The following table gives frost data for several stations:

Dates of killing frosts.

Station.	Average date of first killing frost in fall.	Average date of last killing frost in spring.	Earliest recorded killing frost in fall.	Latest recorded killing frost in spring.
Fresno	Dec. 3	Feb. 23	Nov. 11	Apr. 13
Visalia	Nov. 25	Mar. 10	Nov. 16	Apr. 11
Porterville	Dec. 7	Feb. 8	Nov. 11	Apr. 13
Hanford	Nov. 9	Mar. 16	Oct. 25	Apr. 29

Unusually early fall or late spring frosts sometimes do damage to fruits, but as a rule the various crops are confined to belts within which there is a minimum of danger. Relatively elevated areas with favorable air drainage are least susceptible to frosts as contrasted with flat positions of low gradient on the valley floor.

SUNSHINE, HUMIDITY, AND WINDS.

This area has a higher percentage of sunshine than the lower sections of the San Joaquin and Sacramento Valleys. The summer months are practically cloudless, the average percentage of sunshine

at Frenso for July being reported as 97. Fogs sometimes form in the winter, generally in the night and each morning. They are low and confined chiefly to the lower lands. The average percentage of sunshine at Fresno for January is given as 36.

The area is one of low relative humidity in the summer, the average for July at Fresno being reported as 49 per cent at 5 a. m. and 14 per cent at 5 p. m. The winters are moister; the humidity is given as 93 per cent at 5 a. m. and 71 per cent at 5 p. m. for January at Fresno.

The prevailing winds are from the northwest. They attain their highest average velocity in May and June, being reported at Fresno as 7.3 and 7.7 miles per hour for these months, respectively. Winter rains are often preceded or accompanied by southerly winds.

AGRICULTURE.

HISTORY AND DEVELOPMENT.

The agriculture of this area has passed through transitions similar to those attending the development of most other parts of interior California. The earliest farming was localized along the streams and was subsidiary to mining and stock raising. Relatively few crops were grown, including vegetables, hay and grains, and some fruits. Stock raising was practiced on the open range in the valley, where cattle and sheep were grazed during winter and spring, often being driven to the mountain meadows in the summer. The first railroad construction gave an impetus to agriculture, the most pronounced effect being the sudden increase in the acreage of dry-farmed grain on the valley plains. The stock ranges were rapidly restricted and the area became primarily devoted to growing dry-farmed grains under extensive methods, although wide areas were unfit for grain production either because of alkali or insufficient rainfall. As in other parts of the State, yields of grain were large and profitable in the beginning but decreased later, until it became necessary to fallow the land in alternate years, which practice still prevails over the grain lands. Wheat was largely grown at first, but later was partially displaced by barley.

Grain growing as a dominant factor in the system of agriculture has in turn been supplanted by the production of a wide range of fruits and other intensive, more profitable, crops. This later change, which is still under way, has been due almost entirely to the development of irrigation during the last 30 years.

PRESENT CONDITIONS.

The present agriculture consists chiefly of the production of highly specialized income, or money, crops for export to nearly every part of the country. Fruit products easily rank first in importance; most

of the industries and occupations of the area are centered about fruit growing. Alfalfa and grain growing, dairying, and stock raising are important locally, but usually are confined to regions unsuited to the production of fruits by reason of climate or soil conditions or lack of water for irrigation. The tendency toward specialized fruit crops has been continuous for several decades, and various adverse conditions have only temporarily checked the increase of the fruit acreage. The area is the center of the raisin and fig industries of the United States, and is prominent also in the production of many deciduous and citrus fruits. In the census of 1910 the value of all crops in Fresno County is given as $7,991,187, in Tulare County as $5,353,994, and in Kings County as $3,180,114. These figures do not include the value of animals sold or slaughtered, or of dairy and poultry products. The total, $16,525,295, includes three groups of products: Fruits and nuts (of which nuts are insignificant) total a value of $8,552,958, cereals a value of $2,503,607, and hay and forage crops a value of $4,236,528. These values greatly exceed those of live stock and live-stock products in the area. In the 1910 census the total value of animals sold and slaughtered in the three counties is given as $4,180,268; of dairy products, excluding home use, as $2,667,923; and of poultry and eggs, $993,418.

Climatic and soil factors have an important influence on agriculture, as is indicated by the diversity of industries, based on local variations in one or both of these factors.

Relatively little money is spent for fertilizers. The three counties of the survey in 1910 had 614 farms reporting the use of commercial fertilizer, with a total expenditure of $77,046, or an average of about $125 per farm.

Labor usually is sufficient to care for the crops. The variety of fruit crops with their different periods of ripening gives rather better labor conditions than prevail in many fruit sections. Most of the industries require specialized labor. In the 1910 census the counties of the area report a total expenditure of $6,651,864 for labor on 8,010 farms.

The average size of the farms in Fresno County is reported as 177.2 acres, of which an average of 94.5 acres is improved; in Tulare County as 259.9 acres, of which 126.1 acres are improved; and in Kings County 203.5 acres, with 107 acres improved. These figures include the sparsely settled parts of the counties outside the survey, and represent larger holdings than prevail in the area. The most intensively farmed sections of the survey comprise small, fully improved farms. Large holdings have been subdivided progressively since the advent of intensive agriculture, but there are some estates ranging from several hundred to many thousand acres. The census reports 50.4 per cent of the area of Kings County, 33.6 per

cent of the area of Tulare County, and 29.1 per cent of the area of Fresno County in farm lands. Fresno County reports 5,227 farms operated by owners, 739 by tenants, and 279 by managers; Tulare County, 3,307 operated by owners, 496 by tenants, and 218 by managers; and Kings County, 1,391 by owners, 390 by tenants, and 56 by managers.

Land values have an extremely wide range and are greatly influenced by such factors as irrigation possibilities, climate, and drainage, as well as by the character of the soil. Some of the best soils of the area are the cheapest, owing to a lack of irrigation water, as on the west side of the valley, where some land may be had for $20 an acre or less. On the other hand, certain shallow, hardpan soils, incapable of supporting any deep-rooted crop without blasting, are locally valued at several hundred dollars an acre, owing to their location in the citrus belt. Mature citrus groves on these soils may command a price of $2,000 or more an acre. In general, the cheapest lands of the area are (1) those with very remote irrigation possibilities, which have at the same time little or no value for dry-farmed crops, and (2) the badly affected alkali lands. Values in such cases usually range from less than $20 to $30 or more per acre. The highest priced lands are those which have good soil and location with available irrigation water, and which are adapted climatically to several of the leading deciduous fruits or to citrus fruits. Such lands are valued at upward of $300 an acre. Good alfalfa land ranges in price from a little less than $100 an acre to $200 or more an acre, the higher values usually being attached to lands having some fruit-producing possibilities. Vineyards, orchards, and other developed lands vary greatly in value, but there is often a consistent relation between the value of an orchard or vineyard and its cost as measured by the investment in raw land and expense of development. During periods of low prices for products values tend to become lower, with corresponding increases under the influence of good prices. In the 1910 census the average assessed value of farm land is given as $67.90 in Fresno County, $61.67 in Tulare County, and $69.57 in Kings County.

The principal crops are briefly mentioned below. Most of the crops are discussed fully in special bulletins of the United States Department of Agriculture, the University of California Agricultural Experiment Station, the California State Commission of Horticulture, the California State Board of Agriculture, etc.

GRAIN AND GRAIN HAY.

The production of grain crops, while important, does not compare in extent with that of the northern part of the San Joaquin Valley or the Sacramento Valley. This is due largely to the lower rainfall,

which in much of the area is too low for profitable grain production. As estimated from the United States census for 1910, there were within the area surveyed about 75,000 acres in wheat, 70,000 acres in barley, 2,500 acres in oats, and a negligible acreage of rye. In addition to this approximate total of 147,500 acres of grain, it is estimated that a total of about 100,000 acres of grain was cut green for hay. The greater part of the grain is produced in Tulare County, that cut for hay being about equal in Fresno and Tulare Counties, but much less in Kings County. Yields vary widely on different soils, and also depend on the amount and distribution of rainfall. A greatly varying acreage is dry farmed to grain on the west side of the valley, but the rainfall is not sufficient to insure success. The highest yields of grain are obtained on the lowlands, as around Tulare Lake. The bed of this lake is planted to grain in dry years, when the lake recedes, but there is the ever-present danger of the lake again expanding and drowning out the crop, except where well protected by levees.

Little grain is grown on the higher lands of the east side of the valley, such crops giving way to fruits, which are more profitable wherever water is available for irrigation. On some of the lands where water is not yet available grain is still produced, but the yields are low.[1]

Grain is steadily being displaced by more intensive, irrigated crops throughout much of the area. Summer fallowing and fall planting are the practices generally followed, and combined harvesters are used to harvest the crop. Rotations are seldom practiced in growing grain, because of insufficient moisture, and manure and cover crops have proved of little or no value in maintaining the productiveness of the soil, owing to the lack of sufficient moisture to decompose them properly.[2]

OTHER FIELD AND TRUCK CROPS.

Alfalfa.—Alfalfa is an extensive and popular crop in localities where fruits and vines do not give more profitable returns. In regions adapted to the fruit industries, alfalfa, being less profitable, is grown only in small, scattered fields. It is grown most extensively on the valley floor in Fresno and Kings Counties and on the lower parts of the Kaweah River and Tule River deltas in Tulare County. Small irrigated areas are grown on the west side of the valley, but the insufficient supply of water there restricts the extension of the crop. The 1910 census reports a total of 122,210 acres in Fresno, Tulare, and Kings Counties producing alfalfa, of which only a few thousand acres were outside the area surveyed. Alfalfa is the

[1] Bul. No. 178, Bureau of Plant Industry, U. S. Dept. of Agr., "Improvement of the Wheat Crop in California."

[2] "A Comparison of Annual Cropping, Biennial Cropping, and Green Manures on the Yield of Wheat," Bul. No. 270, Agr. Expt. Sta., Berkeley, Cal.

principal forage crop of the area, the acreage of grass and hay crops, such as clover and timothy, being negligible.

Alfalfa is grown on a wide range of soils, including all textures from sand to the heaviest clay adobe. All the recent alluvial soils and several of the old valley-filling soils are utilized locally, but the best yields are obtained on deep, friable soils of medium or slightly lighter than medium texture and well supplied with lime. Such soils as the loams and sandy loams of the Hanford, Foster, and Panoche series are well adapted to the crop. Soils 6 feet or more in depth are most desirable; hardpan near the surface is very detrimental. Alkali in very small quantities does not prevent the growing of the crop provided a stand can be obtained, but large quantities prohibit its profitable production. Land in which alkali is accumulating through lack of drainage usually is avoided, unless artificially drained.

Irrigation is essential for alfalfa, except in moist subirrigated areas. Where possible the crop usually is irrigated once to the cutting and sometimes oftener, but frequently water is not available during the late summer and fall, which reduces the number of cuttings and the total yield. It is the practice in some localities, notably in Tulare County, to install pumps to supplement gravity water by supplies from underground sources, and some alfalfa is grown by the use of pumped water exclusively. Pumping sometimes has the desirable effect of lowering the water table.

Yields vary widely, depending chiefly upon the depth and character of the soil and the quantity of water available. Many fields yield as high as seven cuttings per season, with a total of 8 or 10 tons per acre, but the average is only about 3 or 4 tons, as fields receiving very little water and little care give very low yields. Alfalfa may be pastured, or cut several times and pastured later in the season.

Much of the alfalfa is fed on the ranches to dairy stock. It is also baled and shipped to the fruit sections, which produce little hay. Little or no alfalfa seed is produced in the area. The price of alfalfa hay varies greatly, but the average price in the stack is about $6 or $8 a ton.

Nonsaccharine sorghums.—A considerable acreage of the nonsaccharine sorghums is raised in widely distributed localities. Among the most popular varieties are the white durra (Egyptian corn), feterita, milo, kafir, and shallu. Dwarf milo and feterita are perhaps the most popular of these. The census of 1910 gives the total acreage of milo and kafir in the three counties of the survey as 16,607 acres. These crops are grown in scattered fields on the west side of the valley, being planted largely on lands which receive intermittent overflow in the winter months, providing the necessary

moisture. A large acreage is grown without irrigation on the naturally subirrigated lands of the east side of the valley, and the crops are dry farmed on the higher lands, with varying success. Irrigation is practiced for best results on the drier soils.

Little attention has been paid to the adaptation of soils to these crops, except that they are generally planted on soils which are less productive of other crops because of alkali or other unfavorable conditions. On the west side of the valley they are grown on the lighter textured soils, such as the sandy loams and loams. On the east side they are grown extensively on soils moderately affected with alkali, and thus unsuited to other crops or on soils unsuited to fruits and having insufficient water for alfalfa. Some of these crops are grown on good, deep alluvial soils of medium texture, in which case the yields are high. The yields are not seriously impaired by small quantities of alkali, but are very low in badly affected fields. These crops are not well adapted to the heaviest soils, although they produce profitable returns on such soils when other conditions are favorable. Light soils yield good crops where proper moisture conditions can be maintained.

The crops are easy to produce and are popular, as they are subject to few diseases, except occasionally smut. Insect pests do little damage, but certain kinds cause some trouble by feeding on the ripening grain. Rotation is necessary to maintain good yields, such crops as beans, sugar beets and grain being well adapted to this purpose. It is possible to grow the crops after harvesting winter grain, or two crops of the sorghums may be grown in one season, the second being cut for ensilage if desired. Harvesting is done by hand or with a binder, the former practice being expensive.

Yields vary from almost nothing to 2 or more tons per acre, the higher yield being possible only on the best watered soils. The average yield is low, owing to the poor soils often used for the crop and the lack of water and care. The market price in Fresno averages about $25 per ton.

Rice.—The introduction of rice growing in the State and its success in the Sacramento Valley has been followed by many plantings in this area, with indications that larger plantings will be made in the near future. The commercial production of rice in the State began about 1910 and has since developed very rapidly, especially in Butte County, where the acreage in rice in 1915 exceeded 15,000. There are no extensive acreages in this area, but numerous small fields give varying results. Most of the crop is grown in scattered plantings on the lower lands in the Tulare Lake basin, largely with pumped water. In many fields, owing to the inexperience of the growers, the average yields are low.

Rice is grown under widely differing soil and other conditions. It has been welcomed as a possible solution of the alkali-land problem. Certain conditions, however, are necessary for its successful production. The crop is best adapted to a heavy impervious soil, but can be grown on soils of light texture provided the water table is high or there is a hardpan or other impervious stratum near the surface to reduce the loss of the surface water by percolation. A large quantity of water, totaling from 5 to 10 acre-feet, is absolutely necessary, as the crop must be kept flooded from the time of germination until ready to harvest. On suitable soils which have carefully been leveled it may be possible to produce good yields with the minimum amount of water mentioned, but on soils of light texture or of less impervious structure the maximum or even greater quantities will be necessary. Drainage must be such that the water may be removed at harvest time. A relatively high percentage of alkali can be tolerated, although the most strongly impregnated soils can not be used.

Under favorable conditions yields of 30 to 40 sacks per acre may be obtained. Great care in leveling the fields and in keeping sufficient water on the crop at all times are of primary importance in obtaining the best results. It is unprofitable to grow the crop where water for irrigation is expensive.

Sugar beets.—During recent years the production of sugar beets in the area has decreased and beet-sugar factories have closed. Recent increases in sugar prices, however, have revived interest in this industry, and during the season of 1916 factories reopened and a considerable acreage of beets was planted. Many of the beets converted into sugar by the local factories are grown farther south in the valley and the acreage grown within the area remains small. Most of the beets in the area surveyed are grown in the lower Tulare Lake basin. According to the census of 1910, about 2,000 acres of beets were grown in the three counties of the survey.

Corn.—About 5,000 acres in the area are devoted to corn. This crop is usually produced on the lower soils and under conditions of higher humidity than the average for the area. The low relative humidity and heat of the summer are unfavorable to the crop. In some of the river bottoms and lowlands corn does well, but in general the crop is not of great importance in the area.

Melons.—A considerable acreage of melons is planted on the lighter-textured soils, especially in Fresno County. Watermelons, cantaloupes, cassabas, and Persian melons are produced. This industry is largely in the hands of Armenians. The prices received fluctuate widely, the highest being commanded by the early product. The price also varies greatly from season to season, and the crops either may be very profitable or may entail considerable loss. The late melons also bring high prices, but they are subject to injury by

rain and frost. The Fresno district is well adapted to melon culture, owing to its favorable soils and climate, but the distance to markets and the fact that it is not among the earliest producing districts of the State are disadvantages. Soils adapted to melon culture are generally profitable producers of grapes and fruits as well, and these crops are generally preferred.

Miscellaneous minor crops.—Numerous other minor crops are grown in the area, some of which, though locally important, are not produced in sufficient volume to be important in the general agriculture. Eucalyptus is prominent, plantings ranging in size from several acres to considerable tracts being scattered throughout the area. Practically no plantings are now being made except as windbreaks. Cotton has been successfully grown but has not become commercially established, and tobacco of the Turkish variety is grown to some extent. It is reported that Fresno and Tulare Counties together produced about 150,000 pounds of tobacco in 1912. There is an evident lack of experience in growing, handling, and marketing the crop. A wide variety of vegetables are produced for home use, and the total acreage of the small gardens is quite large. There are a few important commercial plantings of vegetables and truck crops.

FRUITS.

Grapes.—Grapes are among the most important products of the area. About 75 per cent of the vines are raisin varieties, the remainder consisting of varieties suitable for the making of wine and for table use. The census of 1910 reports 40,687,207 vines in Fresno County, 7,227,491 in Tulare County, and 4,538,732 in Kings County.

Fresno County normally produces considerably more than one-half the raisin crop of the State, which was estimated as 264,000,000 pounds in 1916, and Tulare and Kings Counties produce an important part of the remainder. The most popular varieties of raisin grapes are the Muscat, Sultana, and Thompson Seedless, the last two being seedless. Yields of raisins are heavy, but vary greatly with the variety grown and the soils.

A number of varieties of wine grapes are grown, including the Alicante Bouschet, Grenache, Zinfandel, and several others. Sweet wines constitute the bulk of the wine product. Considerable brandy also is produced. The table grapes are largely of the Malaga, Cornichon, Emperor, Tokay, and Thompson Seedless varieties. The Tokay does not reach the quality here that is attained in other parts of the State, but is marketed earlier.

The grapes are produced largely on the higher lands, being extensively grown in the region around Fresno and southeastward to the

region of Dinuba and Orosi, and to a less extent on the floor of the valley west of Fresno and in Kings County (Pl. III, fig. 1). They are grown on a wide range of soils, varying in texture from clay adobe to sand and representing all the soil series. Grapes are successfully grown on lands underlain by hardpan where it is not too close to the surface and where drainage is good (Pl. I, fig. 2). While not so susceptible to alkali as some of the tree fruits, grapes will tolerate only very slight concentrations, and alkali-affected areas usually are avoided. Muscats do best on medium to fairly light soils and require abundant moisture. The Thompson Seedless gives best results on a deep sandy loam or loamy sand, but makes a good growth on a wide range of soils. Wine and table grapes are grown under widely varying conditions. Malagas thrive on moderately well-drained soils of medium texture. Tokays yield well on the heaviest soils and produce a fruit of high quality, but do not ripen as early as on the lighter types.

Practically all the vineyards are clean cultivated, and as a rule commercial fertilizer is not used. Irrigation is generally practiced except where the soil receives sufficient water through natural subirrigation or is very retentive of moisture. The Thompson Seedless and table grapes usually are staked.

Raisins are largely marketed through the California Associated Raisin Co., which has done much to stabilize the market, and prices for raisins have recently been very satisfactory. Table grapes are packed and shipped to markets throughout the United States. Wine grapes and the culls of both raisin and table varieties are utilized at local wineries.

Deciduous fruits.—Peach growing is a very important industry. It is reported that in 1916[1] there were in the area 50,028 acres, in bearing trees, distributed as follows: Fresno County, 35,000 acres; Tulare County, 7,845 acres; and Kings County, 7,183 acres. Tulare County is reported to have 1,500 acres of nonbearing trees in addition. It is estimated that there are over 5,000,000 trees in the three counties. The census of 1910 reports a total of 3,769,505 bearing peach and nectarine trees in the three counties, of which number the nectarines form a negligible percentage. Fresno County has a greater acreage of peaches than any other county in the State, and the industry in the area as a whole is second only to the production of grapes. Practically all the common commercial varieties of peaches are grown, but among the more important freestone varieties are the Elberta, Muir, Lovell, and Crawford, while the Tuscan, Orange Cling, and Phillips Cling are among the important clingstones.

[1] Monthly Bulletin of the State Commission of Horticulture of California, March, 1916.

The peach industry is well distributed over the east side of the valley, through all the important fruit belts; there are no commercial orchards on the west side. The crop is extensively grown and thrives on the lighter textured, well-drained, alkali-free soils of the Fresno, Oakley (Pl. III, fig. 2), Madera, Foster, and Hanford series, and on other soils. The loamy sands, sandy loams, fine sandy loams, and light loams give best results. Clean cultivation is the usual practice, and pruning, thinning of the fruit, and spraying are essential to success. Most orchards are irrigated, but in some important districts irrigation is not necessary, this being particularly true of certain sections of Kings County where the water table is sufficiently near the surface to subirrigate the trees, although some orchards suffer both from alkali spots and from insufficient drainage. Certain other soils which are retentive of moisture produce fair yields of peaches without irrigation, but it is doubtful if maximum yields can be obtained in this way. The crop matures early and irrigation usually is not so necessary when a scarcity of water prevails in late summer and fall. Cultivation usually is practiced after each irrigation. Small quantities of barnyard manure are applied, but most orchards are not fertilized otherwise. The peach is sufficiently late blooming to be little affected by frosts in this area, and the early maturity of the fruit insures drying before being damaged by early fall rains. Peaches are dried, canned, and sold as fresh or "green" fruit. The green fruit generally is marketed locally or shipped short distances. Sun-drying the fruit prevails, and it is in this manner that the greater part of the crop is utilized. The canning industry is important in the towns and cities of the area; this is one of the important peach-canning sections in the State. The price of dried peaches has recently been low, but the recent organization of a cooperative selling association may result in more stable and profitable market conditions.

Over one-half the fig crop of the State is produced in this area. According to statistics of the State Commission of Horticulture, there are in Fresno County 2,919 and in Tulare County 1,010 acres in figs. Figs are grown extensively as border trees along roads and in yards, the total number of trees thus grown outside the orchard being very large. The common varieties are the Adriatic, the Mission, and the Smyrna, but there are numerous other kinds. The fig is commonly grown from seed, and a number of local varieties have been developed.

Figs are grown chiefly on the higher lands in the general fruit regions, especially in the vicinity of Fresno. They do best on deep, well-drained soils of medium texture, a high water table being unfavorable. Shallow soils, such as those having hardpan near the

surface, do not give good results. On properly selected soils with favorable water conditions the trees attain great size and age, and with good care bear heavily. The length of life of the fig tree in California is not definitely known, but trees over half a century old are still heavy bearers.

The orchards usually are planted with the trees in squares 40 feet apart. While young the land is intertilled, or the orchard may be planted 20 by 20 feet and the alternate trees removed after the trees have attained a size sufficient to render this necessary. The trees bear heaviest where they have plenty of room, as in border rows. Bearing orchards are clean cultivated, and may or may not be irrigated.

The production of apricots is much less important than that of peaches, there being, according to the State Commission of Horticulture, about 4,580 acres of bearing and 963 acres of nonbearing trees in the survey in 1916. This represents a total of about 550,000 trees, which is an increase over 1910, when 359,664 trees were reported in bearing. Fresno and Kings Counties each have about 2,000 acres of bearing apricot trees, while Tulare County has only about 300 acres. Tulare County has about 350 acres and Fresno County about 600 acres of nonbearing apricots. All of the trees are grown on the east side of the valley. Fresno County holds fifth place in apricot production among the counties of the State.

The Tilton, Royal, Blenheim, and Moorpark are the principal varieties of apricots grown in this area. Apricots and peaches are grown on rather similar soils, but soils of medium texture, such as fine sandy loams and light loams, appear better adapted to apricots than those of lighter texture. Low areas usually are avoided because of poor drainage, alkali, and injury from frost. Late spring frosts and rain at blooming time sometimes injure the crops. Irrigation is generally practiced where the larger yields are obtained, but subirrigation seems to supply sufficient moisture in some places, as in Kings County. Little fertilizer is applied to the orchards, although small quantities of barnyard manure are used.

Most of the crop is marketed as dried fruit, an important part is canned, and some is sold as green fruit.

The State Commission of Horticulture reports a total of 4,712 acres of olives in Fresno, Tulare, and Kings Counties, of which more than three-fourths are in Tulare County. Many of the trees are young, but when they come in bearing the crop in this area will constitute an important part of the production of the State. Olives are generally grown in relatively frost-free situations on the higher lands of the fruit belt, and are produced on a wide range of soils, including both deep, recent alluvial soils of light texture and old valley-filling

soils of medium to rather heavy texture, some of which are underlain by hardpan (Pl. I, fig. 2).

The olives are pickled or used for making oil. The highest profits are obtained from pickling olives, both ripe and green fruit being used. Pickled ripe olives are the most common product, but the use of green olives and of dried or Greek olives is increasing. Varieties adapted only to oil production are usually not favored. It is expected that a further development and a more general knowledge of the olive industry will lead to increased markets and profits. Considerable plantings have recently been made.

Tulare County ranks as the fifth county of the State in the number of bearing prune trees, and Fresno and Kings Counties have important plantings in addition. The acreage of plums is relatively small. The State Commission of Horticulture gives the following acreage of bearing and nonbearing prunes and plums: Tulare County, 4,000 acres of prunes and 700 acres of plums; Kings County, 1,109 acres of prunes; and Fresno County, 981 acres of prunes and 343 acres of plums. Nonbearing trees are reported only in Tulare County. Some of the coast valleys and lower Sacramento Valley regions seem better adapted to prune and plum production than most of the San Joaquin Valley.

The French prune is one of the chief varieties grown, and the trees usually are grown on the myrobalan root. The prune thrives best on soils somewhat heavier than those best adapted to peaches, various types of the Hanford and Foster series being very commonly used. Few of the orchards in this area are grown on soils as heavy as a clay loam, but soils of this texture are used elsewhere in the State. Clean cultivation of the orchards usually is practiced, as is customary for apricots. Irrigation is practiced in some situations, but in Kings County many of the naturally subirrigated soils do not require it. The scale is the principal pest of the prune, and this is kept in check with the oil spray. The yields of fruit are probably not so high as on the coast.

The plantings of apples, pears, and cherries are small. The climate does not seem suited to these fruits, and they are grown largely as occasional trees or as minor plantings. They might be grown profitably in certain places with exceptional care, but it is not probable that they will become of great importance commercially.

Citrus fruits.—The most important citrus-fruit region of interior and northern California lies in the relatively frost-free belt along the eastern foothill margin of the valley. The bulk of the citrus fruits of the State are produced in southern California, but the industry is growing rapidly within the area of this survey, especially in Tulare County, which produced considerably over 5,000 carloads

in the season of 1914–15. Kings County does not extend into the citrus-fruit belt and contains no commercially important plantings. Oranges are easily the predominating citrus fruit, with minor plantings of lemon and still fewer pomelo, or grapefruit, trees. The State Commission of Horticulture reports 1,788 acres of bearing orange trees in Fresno County and 19,750 acres of bearing and 22,550 acres of nonbearing orange trees in Tulare County. Of lemons, 75 acres of bearing trees in Fresno County and 62 acres in Tulare County are reported, with 775 acres of nonbearing trees in the latter county. Most of this acreage lies in the present survey, the main exception being some important plantings south of Porterville. Tulare County has about 10,000 bearing pomelo trees, being the second county in the State in this respect, while it ranks fourth in number of bearing orange trees. The Washington Navel constitutes a large proportion of the oranges grown, but the Valencia is locally important.

Plantings of citrus fruits are controlled largely by frost conditions, and this has restricted the industry to the upper valley and lower foothill slopes in the eastern part of the valley. The industry originally centralized in the Porterville, Lindsay, and Exeter regions, but has gradually been extended until a somewhat continuous belt extends from east of Fresno to south of Porterville. The citrus fruits invariably require an unfailing and sufficient supply of irrigation water, and this demand is fully as important as thermal requirements. Owing to the elevated position of the soils in the relatively frost-free localities and their proximity to the foothills they are often incapable of yielding large supplies of water from underground sources and are difficult to irrigate from gravity systems, even where the supply from the latter source is reliable. Many localities along the margin of the valley otherwise favorable to citrus fruits are thus incapable of development at this time through lack of irrigation water. There are important situations, however, where pumping from underground sources gives permanent supplies, and it is largely by aid of this that the industry has become established. Pumping from gravity canals to higher lands is sometimes resorted to, but failure of such supplies must usually be guarded against by having access to an additional underground supply. Lands having both proper frost protection and a reliable water supply are limited and high priced, and this, together with the high cost of irrigation, the rather slow-maturing nature of the trees, and the highly specialized character of the industry, makes the development of even a small acreage of citrus fruits a very expensive undertaking. The total cost of growing an acre of 5-year-old orange trees probably will range under present conditions from about $600 to $900, being in exceptional instances either a little less or more than these figures.

PHOTO FROM UNIV. OF CAL.

FIG. 1.—VIEW OVER AREA OF SAN JOAQUIN SANDY LOAMS, HERNDON, SHOWING HOG-WALLOW TOPOGRAPHY.

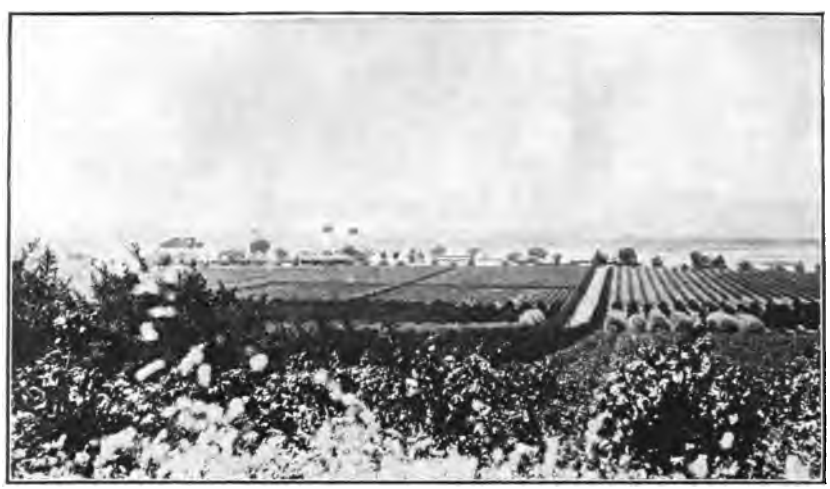

PHOTO FROM UNIV. OF CAL.

FIG. 2.—LOOKING SOUTH ACROSS REDBANK RANCH, WEST OF WOODLAKE.

Oranges and olives on Porterville adobe soils on slopes in foreground; grapes, deciduous fruits, and grain on level San Joaquin loam beyond.

This includes as the principal items cost of land, development of a permanent water supply, trees and planting, care, irrigation, and interest. Groves sometimes pay the cost of their care during their fourth year, and often return a profit during their fifth year.

The citrus fruits are grown on a wide variety of soils, the tendency being to overcome soil deficiencies by additional care and special methods wherever the major controlling factors of frost and water are favorable. The heavy textured adobe soils of the Porterville and Olympic series are prominently used around Porterville and to a less degree farther north. The types of the San Joaquin and Madera series are extensively utilized around Strathmore, Lindsay, Exeter, and Orange Cove, it being necessary to shatter the hardpan with explosives where it lies at shallow depths. Soils of the Hanford series are planted only in a small way, as these and other recent alluvial soils often are not sufficiently elevated for frost protection. Several other soil series are utilized to a minor extent.

The acreage of these fruits, especially oranges, is being increased rapidly considering the heavy investment required and the necessity of growing them in small plantings. The fruit ripens opportunely to command good prices, the Navels preceding those from southern California. Smudging for frost prevention is usually not necessary, and it is possible that more extensive areas are capable of producing citrus fruits than those now thought well adapted to the industry. Several localities, as around Strathmore and Orange Cove, have recently become important citrus-fruit sections.

Miscellaneous and small fruits.—The small fruits are grown only in limited quantities. Numerous varieties of semitropical fruits are grown locally. A few avocadoes are grown in the thermal belt, and possibly the crop will later assume considerable importance in the more frost-free districts. Quinces, Japanese persimmons, and other similar friuts are grown occasionally. A small planting of feijoas, one of the few in California, is located at Sultana. Pomegranates are grown in considerable number but in scattered plantings, especially in Tulare County. The fruit is grown also in hedges or border rows. The acreage in orchard form is increasing on the higher lands. The market for this fruit is limited, although good prices often prevail. Strawberries and various bramble berries occupy a small acreage; together, they are reported on about 350 acres in the 1910 census.

NUTS.

The nut crop is relatively unimportant. There are minor plantings of almonds in the area and a very few of walnuts, although plantings of the latter in recent years total about 250 acres. It is not probable

that the area can achieve the success which attends the coast districts in the production of walnuts, but more extensive plantings may be made. Other nut crops are limited to occasional trees.

ANIMAL INDUSTRIES.

Dairying.—Dairying is locally important in the area, and is nearly always associated with alfalfa production. According to the census of 1910 the dairy products of Fresno County, excluding those consumed at home, were valued at $850,240; those of Tulare County, $983,432; and of Kings County, $834,251. The industry has grown very rapidly since 1900, with increasing attention to improvement of the herds and better marketing of the products. There are many creameries in the area, butter being the principal product, with relatively small quantities of cheese. Fresno County was reported in 1910 as having 22,241 dairy cows on farms and ranges; Tulare County, 26,765; and Kings County, 18,593. The regions described as being important alfalfa producers are almost without exception important in dairying as well. Alfalfa hay or pasture constitutes the only feed for many of the herds, but ensilage, the sorghums, grain, and other feeds are used incidentally or locally. The salt-grass pastures of the alkali lands are often used in conjunction with the alfalfa, especially for pasturing the young stock. Dairying usually is profitable; and while the returns are less per acre than in the case of certain of the fruit industries it is considered a dependable source of income if conducted under well-established methods.

Live stock.—According to the 1910 census there were in Fresno, Tulare, and Kings Counties a total of 307,084 cattle of all ages, including the dairy cows. Some of these cattle are ranged in the hills during the summer, and a small part belong in those parts of the counties not included in this survey. The three counties reported in 1910 a total of 22,976 calves, 66,598 other cattle, 100,482 swine, and 74,637 sheep and goats sold or slaughtered, with 4,812 horses and mules sold. The intensive development of the area tends to restrict the number of cattle on the ranges, but there is an accompanying even greater increase on the farms where general farming or dairy industries succeed the range. Extensive sections are better adapted to pasture than to any other use.

The counties together reported 111,975 hogs of all ages in 1910. Conditions are favorable for hog production, either as an incident of some of the other lines of farming or as a special industry. The feed consists of various products, including alfalfa, the sorghums, grain, and the by-products of the dairy industry.

A total of 225,569 sheep of all ages is reported in the three counties. Many of these are confined to the range portions of the survey, and sheep are not common on the farms, although they are often grazed over tilled land after the crops are harvested. The 1910 census also reports a total of 8,044 goats in the three counties.

There were 58,682 horses and colts and 8,703 mules and colts on the farms in the three counties in 1910, and several thousand additional animals in the cities. They are largely raised for local use.

Poultry and eggs.—The poultry industry is conducted largely as an incident to major forms of agriculture, but there are scattered instances where it is specialized. In the 1910 census the total value of poultry and egg production is given as $419,265 in Fresno County, $325,658 in Tulare County, and $248,495 in Kings County.

Bees.—The census of 1910 reports 9,242, 4,690, and 9,568 colonies of bees for Fresno, Kings, and Tulare Counties, respectively, and the total value of these is given as $83,116. The total value of honey and wax produced is given as $33,356 in Fresno County, $12,028 in Kings County, and $17,434 in Tulare County.

SOILS.

CLASSIFICATION.

The area surveyed is a part of a great structural trough inclosed by mountains. It is believed that the crustal movements accompanying the uplift of the mountains were intermittent, as remnants of old valley deposits are now found at varying elevations above the valley floor. The valley floor has been deeply covered by accumulated wash from the surrounding mountains, the filling processes being still in operation.

The system of soil classification used in this area is similar to that employed in other surveys of the same character in other parts of the State. The soils are largely included within four main divisions or provinces, (*a*) residual soils, or those derived in place from the disintegration and weathering of consolidated rocks; (*b*) old valley-filling and coastal-plain soils, which are weathered and otherwise modified, old, unconsolidated, water-laid materials; (*c*) recent alluvial soils, or those of recent deposition which have undergone no important changes by weathering or internal modifications since they were laid down; and (*d*) wind-laid soils, or those owing their present position and character to wind action.

The first three provinces include by far the greater part of the soils of the State; the residual soils predominate throughout the mountainous parts; the old valley-filling and coastal-plain soils are

prominent along the valley margins as old terraces along streams or as remnants of extensive, modified alluvial fans and mountain footslopes; and the recent alluvial soils prevail over valley slopes and floors covered by recent stream deposits. The residual province is inextensive in this survey, but is widely developed in the adjoining mountains to the east and west. The old valley-filling and recent alluvial provinces include by far the greater part of the soils of the area, and of these the latter is somewhat the more extensive. The soils of wind-laid origin are the least extensive of the four main divisions.

The soils in each division are subdivided into series on the basis of origin, color, structure, subsoil features, topography, and drainage, etc., and each series is subdivided into "types" on the basis of texture, or the relative quantity of sand, silt, or clay present. Soil types are sometimes subdivided into "phases," this differentiation being based upon minor variations in color, gravel content, depth, drainage, or other features. The character of this survey prevents showing all the types and phases separately on the soil map, owing to the small scale of the map and the mixed occurrence of the soils, and in some instances they have been mapped in groups. Such groups usually include only different types of the same series, but occasionally soils of different series have been shown together.

In this way the soils of the area are classified into 39 types or type groups, including Rough stony land, into which, owing to its nonagricultural character, materials of different origin have been thrown.

RESIDUAL SOILS.

The residual soils have been formed in place by the weathering of underlying rocks, and occur in the hilly and mountainous portions of the area. They often have dissected and uneven surfaces. They are typically well drained, and of variable depth, but the parent rock usually is encountered at less than 6 feet. They are frequently associated with Rough stony land and contain varying quantities of rock outcrop. The soils vary greatly in composition, and in this survey are derived from sedimentary, basic igneous, and quartz-bearing igneous rocks.

The sedimentary rocks are principally calcareous shales and sandstones, with smaller quantities of conglomerate. These rocks give rise to the residual soils along the west side of the area and supply most of the material forming the alluvial soils of the adjacent valley slopes. Two series of residual soils derived from sedimentary rocks, the Kettleman and Arnold series, are recognized in this survey, the former being the more extensive.

The basic igneous or quartz-free rocks are prominently developed, and weather into rounded hills and uniform slopes with heavy-textured soils predominating. The Olympic series, with minor undifferentiated bodies of soils belonging to the related Aiken series, is the only series derived from this character of rocks mapped in this survey.

Igneous rocks are slightly less extensive in the area than those of sedimentary origin and are confined to the Sierra foothills along the eastern margin of the survey. Those of granitic character break down rather unevenly and form irregular surfaces with frequent rock outcrop and often with extensive areas of Rough stony land. Soils of the smoother areas of granitic origin are mapped as the Holland series, but include small undifferentiated bodies of soils belonging to the related Sierra series.

OLD VALLEY-FILLING AND COASTAL-PLAIN SOILS.

The soils of this province are extensive in the area, and consist of unconsolidated, water-laid deposits which have undergone marked changes in soil and subsoil and frequently in topographic features since they were laid down. They vary widely in color, organic-matter content, and mineral composition, and their heavy, compact subsoils and substrata are often among the most important features which distinguish them from soils of other provinces. They vary greatly in topography, but usually occupy sloping or rolling surfaces or remnants of old, partially eroded alluvial fans or stream terraces which have either been elevated since the soils were laid down or have been left in their present elevated positions by streams cutting deeper channels through them. They usually lie intermediate in position between the residual and recent alluvial soils and differ from the latter in that they are undergoing active erosion or are slowly being covered by the deposition of additional material. Their poorly aerated and less permeable subsoils usually make them less desirable for deep-rooted crops and less capable of properly supplying moisture to growing crops. Eight soil series, the San Joaquin, Madera, Pleasanton, Antioch, Porterville, Fresno, Merced, and Montezuma, are recognized in the survey as belonging in the group of old valley-filling and coastal-plain soils.

RECENT ALLUVIAL SOILS.

The soils of recent alluvial origin are not only the youngest soils of the survey, but also in most of the areas mapped are still in process of formation. They usually have a smooth surface, and both

soil and subsoil are generally open and permeable, as contrasted with the more uneven surfaced old valley-filling soils, which often have heavy-textured, compact, and poorly aerated subsoils.

The recent alluvial soils cover most of the broad plain of the west side of the valley, and extensive areas occur in Kings County and along the larger streams of the east side. They characteristically occupy broad, gently sloping alluvial fans, valley slopes, and stream bottoms, but as occurring in this survey include a few types deposited in the stagnant waters of broad, flat, overflow basins and lakes. They are derived from a wide range of rocks, including shale, sandstone, conglomerate, granite, and various basic or quartz-free igneous rocks. They rank among the best agricultural soils of the area and are suited to a very wide range of crops where water is available for irrigation. Much of their extent is well drained, but bodies along the valley trough, in nearly flat or slightly depressed positions, or those unfavorably located along stream bottoms frequently have a high-water table and are affected more or less by seepage and alkali.

The soils derived as wash from sedimentary rocks are extensive, but are confined to the west side of the valley trough. The Panoche and Laguna series are represented. Those derived predominantly from granitic rocks include the Hanford, Foster, and Chino series, and those of undetermined or mixed origin are represented by the Sacramento series.

WIND-LAID SOILS.

The soils of this province are quite extensive in the area, being mainly confined to that part of Fresno County from Clovis south and southwest to Kings River. The soils cover low, undulating, wind-formed ridges and are closely associated with the sands of the Fresno and Madera series. They are quite uniform, and drainage is good. They consist mainly of material blown from the Fresno and Madera series, and differ from them in surface configuration, hardpan, and subsoil features.

The Oakley series is the only representative of the province in this survey.

MISCELLANEOUS MATERIAL.

This includes a single class of material, Rough stony land, which is practically nonagricultural in this area. A small amount of undifferentiated Rough broken land is included in the Rough stony land as mapped.

The following table gives the actual and relative extent of each type or type group mapped:

Areas of different soils.

Soil.	Acres.	Per cent.	Soil.	Acres.	Per cent.
Panoche loams	358,144	12.6	Porterville adobe soils	44,800	1.6
Panoche clay loams	280,320	9.8	Madera loam	34,048	1.2
Hanford fine sandy loam	246,016	8.6	Sacramento clay	26,624	0.9
Fresno sandy loam	47,872	6.8	Oakley and Madera sands, undifferentiated	24,832	0.9
Brown phase	143,872		Hanford sands	23,296	0.8
Fresno fine sandy loam	114,944	5.2	Antioch loam and clay loam	22,016	0.8
Brown phase	34,560		Sacramento clay loams	18,432	0.6
Madera sandy loams	136,192	4.8	Kettleman sandy loams	17,920	0.6
Oakley and Fresno sands, undifferentiated	129,792	4.6	Laguna loam and sandy loam	15,872	0.6
Foster sandy loams	128,768	4.5	Holland loam	15,360	0.6
Rough stony land	117,760	4.1	Holland sandy loams	14,848	0.5
Chino and Foster loams, undifferentiated	115,456	4.1	Pleasanton loam and sandy loam	12,800	0.5
San Joaquin sandy loams	109,312	3.8	Montezuma clay adobe	11,520	0.4
San Joaquin loam	85,760	3.0	Olympic adobe soils	7,680	0.3
Merced clay loams and clays	83,456	2.9	Hanford loams	7,168	0.3
Fresno loams	81,152	2.9	Arnold sandy loams	6,400	0.2
Heavy phase	1,536		Panoche adobe soils	6,400	0.2
Panoche sandy loams	70,912	2.5	Madera clay loams	6,144	0.2
Merced loams	63,744	2.2	Olympic loams	5,120	0.2
Kettleman loam and clay loam	61,952	2.2	Pleasanton and Antioch loams and clay loams, undifferentiated	2,304	0.1
Hanford sandy loam	60,160	2.1	Total	2,846,720	
Fresno and Merced loams, undifferentiated	51,456	1.8			

SOILS FROM RESIDUAL MATERIAL.

Kettleman Series.

The soils of the Kettleman series are derived from interbedded calcareous shales, sandstones, and conglomerates. They range in color from light gray to gray and include some brownish variations. They often appear browner when the soils are wet. The subsoils usually are similar or slightly lighter colored and more compact than the surface soils, ranging from light gray or gray to brownish gray, with textures similar to or slightly heavier than the surface material. Bedrock usually is encountered at depths of less than 6 feet. Both the surface soil and subsoil are generally calcareous, effervescing freely with acid. The series occupies gentle slopes, rounded hills, or mountainous areas. The soils are shallowest and most eroded on steep slopes, where occasional rock outcrop is present. They are generally treeless and but sparsely covered with grasses. Drainage is well developed and usually excessive. Owing to prevailing conditions of low rainfall and lack of water for irrigation, the series is of

little agricultural importance and is utilized mainly for grazing. The series is quite extensive in this survey, and is represented by two groups of soils, the Kettleman sandy loams and the Kettleman loam and clay loam.

KETTLEMAN SANDY LOAMS.

The Kettleman sandy loams as mapped include the sandy loam and fine sandy loam types, of which the former is the more extensive.

Description.—The Kettleman sandy loam is a light-gray to gray or light brownish gray medium to coarse textured friable sandy loam, varying in depth from 8 to 20 inches. The type has been developed under arid conditions and on this account has a low content of organic matter. The subsoil is rather open and porous also. Gravel and stones occur in small quantities over the surface, but do not materially affect tillage. The subsoil is similar to or heavier than the surface soil and ranges from gray or light gray to brownish gray in color. It generally rests upon sandstones and shales at depths of less than 6 feet, and contains local concentrations of calcareous material.

The fine sandy loam differs but little from the sandy loam except in texture. It consists of light-gray to gray or brownish-gray medium to heavy textured fine sandy loam of somewhat more compact structure and of higher organic-matter content than the sandy loam. The type is retentive of moisture and tillage is not difficult.

The group as mapped varies little, except in gravel content, the occurrence of minor included bodies of loam or clay loam texture, and occasional exposures of the subsoil where erosion has been most active. Some of the more brownish and less calcareous variations approach in character the related Altamont soils, which are of similar origin.

Location.—The Kettleman sandy loams are not extensive. One body lies northeast of Coalinga, forming a part of Anticline Ridge, two bodies skirt the hills north and south of Cantua Creek, and another occupies the lower slopes of the Kettleman Hills.

Topography and drainage.—The Kettleman sandy loams have a varied topography and occur chiefly on rolling hills of low elevation and as slopes along the lower margin of the heavier types of the Kettleman series. The surface of the body northeast of Coalinga is rather uniform and smooth, while that of the other bodies in the area has been subjected to more or less erosion, which sometimes affects their value for farming. Rock outcrop is uncommon, owing to the feebly cemented and readily weathered underlying shales and sandstones. The soils have good drainage, but are not well adapted to irrigation.

Utilization.—These soils are largely untilled and are used almost entirely for pasture. Some small areas are used for the production of grain, but the yields are low and uncertain.

KETTLEMAN LOAM AND CLAY LOAM.

The Kettleman loam and clay loam include the loam and clay loam of the Kettleman series, and of these types the former is the more extensive.

Description.—The Kettleman loam consists of about 10 to 12 inches of a gray to light-gray or light brownish gray loam. The soil is friable, but less so than that of the Kettleman sandy loams. It is low in content of organic matter in its shallow phases, but where deeper it is better supplied with this constituent and retains moisture moderately well. Gravel and stones are of only local occurrence. The subsoil where distinctly developed is somewhat heavier and more compact than the surface soil, especially in the deeper phases. It usually consists of a heavy loam or clay loam of lighter color than the surface material. The soil sometimes rests directly upon the underlying shales and sandstones without an intervening distinct subsoil. The total depth of soil and subsoil ranges from about 1 foot to several feet, although bedrock typically is encountered at less than 6 feet.

The Kettleman clay loam consists of a clay loam having about the same range in color and depth as the Kettleman loam. It is less friable, averages slightly darker in color, and apparently is higher in organic matter than the loam.

The soils of this group in general are uniform and typical, though some local variations occur. Some of the browner and less calcareous variations approach in character the related Altamont soils, which are of similar origin and occur in the slightly more humid regions along the margin of the valley.

Where the soils occupy saddles between hills they are generally deeper than the average, and bedrock may lie below the depth of 6 feet. In these places some colluvial material derived from the steeper adjacent slopes is included. In some cases the soil is reddish in appearance, as northwest of Coalinga, where gravel is also present in the subsoil.

Origin.—The parent material of the soils of this group as occurring in this survey is derived in part from unconsolidated deposits, but typically from shales and sandstones. Gypsum is often prominent in the parent rocks.

Location.—This group of soils covers about 98 square miles. The largest bodies lie in the Kettleman Hills, around Oilfields, and near Coalinga, in the southwestern part of the survey. Narrow bodies

extend from the region of Panoche Creek to the northern edge of the area, and narrow valleys sometimes indent the valley margins.

Topography and drainage.—The surface ranges from gently rolling to dissected, steep, and hilly. It is often considerably eroded, with frequent rock outcrop, especially in the higher portions. Drainage is good to excessive. The topography of the greater part of the group is favorable to tillage.

Utilization.—The Kettleman loam and clay loam are covered by a scant growth of grass and scattered brush, with no tree growth. They are not tilled, chiefly because of the lack of water. Much of the group is remotely situated, and it seems suited only to pasture. Irrigation is impracticable at this time, but may eventually be supplied to some of the outer slopes and hills. Some important oil fields are located within areas of these soils. The value of the land for agriculture is very low.

Arnold Series.

The Arnold series is residual from the same class of rocks that gives rise to the Kettleman series. The soils range in color from gray to light brownish gray and include some light grayish brown phases. They usually become browner when wet, are low in organic matter, easily tilled, and typically rest on bedrock at a depth of less than 6 feet. The subsoil is gray, light brown, or brown, and similar to or slightly heavier than the surface soil in texture. Concentrations of lime in the subsoil sometimes occur, but less abundantly than in the Kettleman series. The Arnold series occupies gentle slopes, rounded hills, or mountainous areas. The soils are shallow and eroded on the steeper slopes. Rock outcrop sometimes occurs. The soils are well to excessively drained, and are droughty in many places in the summer. They are often devoid of trees or brush in their native state. The series is differentiated from the Kettleman series mainly on the basis of its lower content of lime in the soil and subsoil. The series is represented by a single soil group, the Arnold sandy loams.

Arnold sandy loams.

The Arnold sandy loams group includes the sandy loam and fine sandy loam, with a small percentage of a light-textured loam.

Description.—The Arnold sandy loam usually consists of a light-gray, gray, or slightly brownish gray sandy loam of powdery or ashy appearance under field conditions. It is generally free from gravel or stone, although some very fine gravel is encountered in places. Much of the grayish color is due to the presence of light-colored particles of shale; when moist the soil becomes more brownish. Distinct differences between the soil and subsoil are unusual, although feebly

consolidated beds of shaly or sandy material sometimes occur within the 6-foot section.

The Arnold fine sandy loam closely resembles the sandy loam, except in texture, and indefinite gradations between the two types are common.

The Arnold loam is of comparatively light texture, and its powdery, dry condition usually makes it appear even lighter than it really is. Like the other members of the series it is frequently without a distinct subsoil. It is apparently low in organic matter.

Origin.—The Arnold soils in this area are derived from less firmly cemented shales and sandstones than is usually the case, and much of the parent material is only partially consolidated.

Location.—The group covers 10 square miles. The principal area extends about 10 or 12 miles along the western edge of the area southwest of Mendota, with a smaller detached area northwest of the larger one. The Guijarral Hills east of Coalinga are covered in part by these soils. Small undifferentiated areas are included in the soils of the Altamont series. The Arnold soils occupy the same general regions as the Kettleman soils, and the boundaries between them usually are indistinct.

Topography and drainage.—The Arnold sandy loams are rolling or hilly in part, but contain some gentle slopes which merge toward the valley with the recent alluvial soils. A choppy or sharply eroded surface marks some of the area east of Coalinga and this is much more pronounced and prevalent in the elongated areas farther north. The ravine slopes as a rule are usually too steep for tillage, but probably more than three-fourths of the area of the group is tillable so far as surface features are concerned. The soils lie in regions of extremely low rainfall. Both surface and subsurface drainage are thorough to excessive.

Utilization.—The soils of this group are not tilled and have only a moderate value for pasture. The low rainfall makes dry farming hazardous even on the best soils of the region, and the Arnold soils are practically useless for this purpose owing to their excessive drainage and low water-holding capacity. The possibility of irrigation is remote, as the west side of the valley comprises considerable better unirrigated land.

Olympic Series.

The soils of the Olympic series are brown or rusty brown, with some dark-brown and grayish-brown variations. They are dense and compact in the heavier textured areas and are sometimes relatively high in organic matter. The subsoils are brown, light brown, grayish brown, or reddish brown in color and similar to or heavier than the surface soil in texture. Bedrock usually is encountered at less

than 6 feet from the surface. The topography is rolling, hilly, or mountainous, but the surface is in many places smooth. Drainage is good, and on the steeper and shallower slopes the run-off is relatively large. The soils differ from the related Aiken soils in color and content of organic matter. The soils are mapped in two groups, the Olympic loams and the Olympic adobe soils.

OLYMPIC LOAMS.

The Olympic loams include the loam and clay loam types of the series and small undifferentiated bodies of reddish-brown or red soils which if sufficiently extensive to warrant separation would be mapped with the Aiken series.

Description.—The Olympic loam is the most extensive. It consists of a brown, light-brown, or grayish-brown loam ranging in depth from 10 to 18 inches. It is somewhat sticky and darker colored when wet, but usually has a friable structure and is not difficult to till, except where the slope is steep or bedrock lies near the surface. Some subangular rock fragments of the size of gravel and cobbles are present locally, but rarely in sufficient quantity to interfere with tillage. There is little rock outcrop. The soil contains a moderate percentage of organic matter and is quite retentive of moisture in its deepest areas, but much of the rainfall is lost in the run-off on the steeper slopes and where the soil is shallow. The subsoil is a light-brown or reddish-brown loam or clay loam which is somewhat more compact than the surface soil. It contains some rock fragments and at depths varying from 1 foot to 5 feet or more rests upon the parent basic igneous rocks. Lime, as conspicuous concentrations in either soil or subsoil, usually is absent, but locally it forms grayish mottlings in the subsoil. The transition from the subsoil to the unaltered rock is more sudden than in soils derived from granite rocks.

The Olympic clay loam is brown to dark brown in color. It has a somewhat higher organic-matter content than the loam, more lime in the subsoil, a greater tendency toward an adobe structure, and is more difficult to till.

The soils are quite uniform in most of the areas, but the types are more or less intermixed in their occurrence. Several small areas of the Aiken loam are included, as north of Clovis and in the region northeast of Orosi. The Aiken soils are red or reddish in color, and readily distinguished from the Olympic types.

Location.—The group is inextensive; it covers a total of 8 square miles. It occurs in a number of rather small areas along the foothills on the east side of the valley from Orosi northward, and is most prominently developed several miles north of Clovis and northeast of Centerville.

Topography and drainage.—The surface features are variable. The soils occupy gentle foothill slopes to somewhat dissected and rolling areas. The surface is often relatively smooth and uniform, except for occasional rock outcrop, but in general is unfavorable for irrigation. Drainage is good to excessive. Much water escapes in the run-off on the shallower and steeper areas.

Utilization.—This group of soils is of little importance at present, and is mainly utilized for pasture. Small acreages of grain and hay are grown, giving low yields. Cultivation is mainly confined to dry farming, on account of the difficulty of obtaining water for irrigation. Pumped water is supplied to small plantings of fruits. Land prices are often low and are based upon the value of the soil for grain and for pasture.

OLYMPIC ADOBE SOILS.

The Olympic adobe soils include the clay adobe and the clay loam adobe of the Olympic series. It is probable that the extent of these soils is about equal.

Description.—The Olympic clay adobe usually consists of a brown or dark-brown clay. When wet the soil is sticky and untillable, but when dry it has typical adobe structure, cracking and subdividing until reduced to a relatively pulverulent though still granular condition. This condition of structure, in extreme instances known as "dry bog," is a distinct aid to tillage where the soil is handled under proper moisture conditions, although there is a narrow range in moisture content within which effective tillage is possible. The soil contains considerable organic matter. Some portions are stony or gravelly, and rock outcrop marks the shallower phases or those bordering areas of Rough stony land. The surface soil in some instances extends to the underlying bedrock without distinct change, but in its deeper phases the type gives way at depths of about 16 inches or more to a lighter colored and in places lighter textured subsoil which in turn grades into the underlying rock. The deepest areas are more than 6 feet in depth, the greater depths occurring on lower footslopes and in swales. Shallow soils and rocky surfaces often occur in a zone of gradation between the soil and the Rough stony land, and the boundaries as shown on the map are largely arbitrary.

The Olympic clay loam adobe does not differ greatly from the clay adobe in any particular except texture.

The group contains minor variations. The body lying in sections 9 and 10, about 2 miles east of Orosi, is red and represents heavy material of the Aiken series, which is similar to the Olympic in most features except color. Some of the areas are very dark brown or

dark grayish brown, and closely approach the dark-gray to black Climax soils. The Olympic soils sometimes extend well down on the hill slopes and merge with the lower lying old valley-filling soils and in such positions some old valley-filling material may be included.

Location.—The soils of this group are comparatively inextensive, covering in this survey 12 square miles. They occur in several elongated areas, usually on marginal slopes around the base of some of the foothills along the eastern edge of the survey. On their upper margin they usually are bordered by Rough stony land.

Topography and drainage.—The surface varies from gently to steeply sloping or hilly, some of the areas showing little variation in topography. Surface drainage and subsurface drainage are generally good. Practically all the areas are capable of tillage and are adapted to irrigation, although the surface is often rather steep and here cultivation is laborious.

Utilization.—These soils are important in the production of citrus fruits owing to their relatively elevated position and consequent freedom from frost. They have been irrigated in many places with pumped water, and support some valuable orchards. Some of the deciduous fruits and grapes are grown under irrigation, but the cost of development seems to prohibit all but the most remunerative crops. Dry-farmed grain and hay are sometimes grown. A large part of the group is only intermittently cultivated. Land values vary greatly, depending upon the character of the orchards in the developed areas and upon the possibilities and ease of irrigation in the undeveloped holdings. The tendency is to increase the intensive use of the soil with the aid of pumped irrigation water. The practice of thorough tillage, proper irrigation, the growing of cover crops, and the use of stable manure greatly reduce the difficulties of handling these heavy-textured soils.

Holland Series.

The Holland series is derived from granitic rocks. The soils are brown in color, with grayish-brown and reddish-brown variations. They are micaceous and friable, with light-brown, reddish-brown, or yellowish-brown subsoils, which are of the same or heavier texture than the surface soils and generally somewhat more compact and less permeable. Partially weathered or unaltered bedrock is generally encountered at a depth of less than 6 feet. The soils are low in organic matter, but are not difficult to till except where steep and hilly. The topography is rolling, hilly, or mountainous, but the surface is generally smooth except for some rock outcrop in places. The soils are well drained, and in the steeper and shallower areas the run-off is large. The series is represented in this survey by the Holland sandy loams and the Holland loam.

HOLLAND SANDY LOAMS.

The Holland sandy loams group includes the coarse sandy loam, sandy loam, and fine sandy loam, the latter being of least extent. Small areas of Sierra material are included.

Description.—The Holland coarse sandy loam typically consists of a brown, light-brown, or grayish-brown coarse sandy loam, usually of gritty and friable character. It is micaceous, apparently low in organic matter, and permeable to water. The coarse nature of the type is largely due to included particles of the granitic parent rocks. Rock outcrop occurs, its extent depending largely on the topography and depth of soil material. The surface soil in exceptional cases extends to depths of 6 feet or more without distinct change in texture or color, but more often it grades below an average depth of 12 inches into a yellowish-brown or reddish-brown subsoil which may be more compact and of heavier texture than the surface soil. Bedrock is reached at depths ranging from a few inches to 6 feet or more, and usually is approached through zones of fairly permeable disintegrating rock material.

The Holland sandy loam is not essentially different from the coarse sandy loam, except in its finer texture. It is somewhat more retentive of moisture than the coarser type, and often has a more distinct subsoil.

The Holland fine sandy loam, which is of relatively small extent, consists of a brown, micaceous fine sandy loam similar in most features to the other types of this group, although sometimes a little darker in color.

The small areas of reddish-brown to red Sierra material are most prominent east and northeast of Orosi.

Location.—The group is relatively inextensive and occurs in numerous small bodies along the foothills in the eastern part of the survey. Some of the areas cover several square miles, while others are very narrow and difficult to show on the map. The soils are most prominent in the vicinity of Friant and southeastward to Lincove.

Topography and drainage.—The group Holland sandy loams occupies rolling, hilly, or moderately sloping areas, with drainage well developed. The surface as a rule is not severely eroded, and the soils are generally tillable and capable of irrigation development if water could be made available. Although most of the surface is typical of that of the residual soils, some footslopes or partially filled swales have a subdued topography. Here the soil is of colluvial origin.

Utilization.—Most of these soils lie above irrigation systems and in positions where pumping water for irrigation is difficult and expensive. The low rainfall prohibits all dry-farmed crops except hay and grain, which give only moderate yields. For these reasons the soils

are in the main of little agricultural importance, and some of the more extensive areas are only intermittently farmed. Water has been supplied in small quantities by pumping to irrigate some small citrus-fruit orchards. The soils are adapted to these fruits and others wherever the topography, depth of soil, and water supply are favorable.

HOLLAND LOAM.

Description.—The Holland loam to a depth of 10 to 24 inches consists of a brown or grayish-brown, rather coarse textured, micaceous, friable loam. It rarely carries rock fragments or gravel. The soil is rather low in content of organic matter, but is easily tilled where the surface is favorable. It is retentive of moisture in its deeper areas, but droughty where shallow. The subsoil is a brown or reddish-brown, micaceous, heavy-textured loam or clay loam, usually free from gravel and with a somewhat more compact structure than the surface soil. The subsoil rests upon partially weathered or solid granite at depths ranging from 1 foot to several feet, usually less than 6 feet. The granite weathers quite uniformly and very little rock outcrop occurs. The deeper subsoil and partially weathered granite are unfavorable to root development and the movement of water.

The type is quite uniform in texture, but in places the surface material approaches a sandy loam. Small areas of Sierra loam and sandy loam are included. These soils are reddish brown to red, but resemble the soils of the Holland series in most features except color.

Location.—The Holland loam, which is inextensive, is confined to the foothills along the eastern edge of the survey. It occurs in a number of areas east and north of Woodlake, east of Strathmore and Porterville, north and northeast of Centerville, and northeast of Clovis. It covers a total area of 24 square miles.

Topography and drainage.—This soil occupies hilly or mountainous country, usually of moderate slope and free from sharp dissection. Its elevation is such as to give it good drainage. Much of the rainfall is lost as run-off, but little or no gullying has taken place. The type occurs at an elevation of several hundred feet above the plains, which renders irrigation costly and difficult.

Utilization.—The Holland loam is of little agricultural importance in this area. It is mainly in large holdings and is used for pasture and for dry-farmed grain. Land values vary greatly, depending upon location, depth and uniformity of the soil, and possibilities of irrigation. Irrigation is required for fruits and most intensive crops, but water has been supplied on only a very small acreage.

SOILS FROM OLD VALLEY-FILLING AND COASTAL-PLAIN MATERIAL.

San Joaquin Series.

The soils of the San Joaquin series consist of weathered and greatly modified, old, unconsolidated water-laid material, usually derived from a wide variety of rocks. They are typically red or light red, but include pronounced variations of reddish brown that appear redder when wet. At depths varying from a few inches to 3 feet or more the surface soil grades into a thin layer of redder, heavier textured, compact material which in turn rests upon a red or reddish-brown indurated hardpan of varying thickness. The substratum below the hardpan is permeable, except in a few localities where it consists of soft sandstone over which the San Joaquin material has been deposited. The combined depth of the soil and subsoil varies considerably, but averages from 2 to 3 feet. The soils are low in content of organic matter, are without conspicuous concentrations of lime, and bake and become droughty in the summer. They occupy gently sloping to undulating valley plains, usually occurring as elevated areas along the valley margins adjacent to the foothills. The surface is frequently marked by "hog wallow" mounds (Plate I, fig. 1) with inclosed minor depressions in which water stands in wet weather, making the soil very boggy at such times. The soils are typically free from alkali and have little or no tree or shrub growth. The series is represented in this survey by the San Joaquin sandy loams and the San Joaquin loam.

SAN JOAQUIN SANDY LOAMS.

The group San Joaquin sandy loams includes the San Joaquin sandy loam and fine sandy loam and also small bodies of soils of heavier texture. The two main types are about equal in extent and importance.

Description.—The San Joaquin sandy loam consists of a pronounced reddish-brown or red, nonmicaceous, heavy-textured, gritty sandy loam often closely approaching a loam in depressions and over the more nearly level areas. The red color is intensified under moist conditions, but when dry the soil is typically reddish brown. When wet the soil is sticky and boggy and almost impassable, owing to a saturated condition above the hardpan. The soil lacks the friable structure of the sandy types of the more recent sedimentary soils, and its poor granulation usually causes it to bake and form a cloddy surface when tilled. If handled at the proper time, a good seed bed results, but the surface of untilled fields is hard and compact. The soil is usually lighter in texture and deeper on the tops

of hummocks. At depths usually less than 18 inches the soil grades into a loam or clay loam, the heavier texture prevailing immediately above the hardpan. The subsoil is generally redder in color than the surface soil, and at depths ranging from 18 to 36 inches or more it rests upon an indurated reddish-brown hardpan from a few inches to several feet in thickness. The hardpan occurs throughout the type and usually checks the downward movement of water and the development of roots. The substratum beneath the hardpan is mainly a friable sandy loam or loam and is favorable for root development when the hardpan is broken up. The depth and thickness of the hardpan have an important bearing on the value of the land. Where less than 4 feet below the surface it requires shattering for best results with tree fruits, alfalfa, and many other of the deeper rooted intensive crops. The type usually contains no apparent concentrations of lime. Some gravel is present locally near the foothills and minor spots of heavier textured, and darker colored soils occasionally mark the depressions among the hummocks.

The San Joaquin fine sandy loam closely approaches the sandy loam in all features except its somewhat finer texture. It is less uniform, however, and includes many small spots of loam or clay loam, which occupy small depressions and the flatter areas.

The soils of this group are distinct from associated soils. They may include some undifferentiated material of the Madera or other related and adjacent series.

Location.—The group is extensive in this survey. The largest areas occur in the region east and west of Clovis, in the vicinity of Reedley, north and northeast of Sanger, north of Fresno, southwest and northwest of Porterville, in the region around Woodlake, and in a number of other places along the east side of the valley. The soils occupy the plains and usually occur at a considerable distance east of the valley trough.

Topography and drainage.—The San Joaquin sandy loams occupy remnants of a series of broad, gently sloping old alluvial fans, usually well above present stream channels. Areas nearest the foothills have the most uneven surfaces, due to more active erosion. The surface in general is gently sloping and marked by numerous rounded hummocks, 1 foot or more in height and 15 to 25 feet in diameter (Pl. I, fig. 1). Considerable leveling is necessary to fit the land for irrigation. The soils have sufficient slope to give good surface drainage, but many of the depressions among the hummocks are covered with standing water during wet weather. This has a tendency to puddle the soil and either reduces yields or entirely destroys the crop in such places. The shallow hardpan restricts subsurface drainage and keeps much of the subsoil in a saturated

condition during the wet season. The water table is deep and practically no damage from seepage or alkali occurs.

Utilization.—The soils are nearly all under cultivation, but owing to their hummocky, uneven surface, their hardpan, and the scarcity of irrigation water, they have been utilized mainly for dry-farmed grain and grain hay, with moderate to low yields. In recent years some of the deeper and more desirable areas have been utilized for the production of grapes and peaches and to a less extent of figs and olives without irrigation, but irrigation is necessary for the best results with all fruits and intensive crops. Water has been supplied by pumping or from gravity canals in some regions, as about Reedley, Exeter, Lindsay, Porterville, Strathmore, and Clovis, and favorable locations have been successfully planted to citrus fruits, olives, figs, pomegranates, and other deciduous fruits and intensive crops. Alfalfa usually is short lived where the soils are shallow, but does very well in the deeper areas with irrigation. Shattering the hardpan by blasting has proved profitable where orchards are set, permitting deeper root development and supplying needed subdrainage. The soil is deficient in organic matter and is much improved by the use of manure and cover crops. Some commercial fertilizer is used for citrus fruits, but organic matter is one of the most needed soil constituents. Land values vary widely and depend upon location, depth of the soil, uniformity of the surface, availability of irrigation water, and local development.

SAN JOAQUIN LOAM.

Description.—The San Joaquin loam, to a depth of 8 to 24 inches, consists of a reddish-brown or red, rather compact, poorly granulated loam, which is sticky and of more pronounced red color when wet. In places it carries small quantities of coarse sand and fine gravel. The soil bakes and becomes hard when dry unless carefully handled, but if tilled in the right condition as regards moisture it works into a good seed bed. The soil is low in organic matter, and responds readily to applications of manure and the use of cover crops. The subsoil, which usually becomes heavier in texture and redder in color with depth, ranges in texture and structure from a compact, poorly aerated sandy loam to a clay loam. It typically rests upon the hardpan characteristic of the series at depths of 2½ to 4 feet. This finely cemented stratum lies near the surface in the intervening depressions, and is occasionally exposed on the lower hummock slopes. The substratum below the hardpan is in many places a permeable loam which favors root development when the hardpan is shattered. The condition of the soil mass indicates an advanced stage of weathering and oxidation.

In general, the San Joaquin loam is uniform in texture and structure, but in areas of pronounced hog-wallow surface the soil in the depressions frequently is a clay loam, and that on the tops of the mounds may be much lighter. Small, irregular spots of clay loam and sandy loam occurring elsewhere are included with the type. Areas of clay-loam texture lie near Reedley and east and north of that place. These sometimes occur as meandering, slightly depressed flats, surrounded by the San Joaquin loam, or as more extensive bodies not differing in topography from the latter type. Some of the type northeast of Woodlake lies in a cove, and is bordered by residual soils. The soil in this cove is of mixed character, including not only the San Joaquin loam but also small areas of both residual and recent alluvial or footslope soils. Unimportant areas of Madera loam and Alamo clay adobe are also included with the type as mapped.

Location.—The San Joaquin loam covers about 134 square miles. It is most extensive in the plains region east and north of Strathmore, near Orangehurst, southwest of Lindsay, in the region of Woodlake and Orosi, east and northeast of Reedley, east and south of Seville, in Clarks Valley, and near Porterville. A number of other quite extensive bodies lie northeast of Clovis.

Topography and drainage.—This soil is confined to the east side of the valley, where it occupies gently sloping old alluvial fans, deposited by the large streams before they were intrenched in their present positions. The surface is in general nearly level, but in detail distinctly hummocky. Occasional small, intermittent streamways have furrowed the surface in places, giving it an undulating appearance. The slope usually is ample for good surface drainage, but the hardpan checks the percolation of water and causes the subsoil to become saturated and boggy during the rainy season. Drainage in the depressions is poor, water standing in them during the rainy season. The surface requires considerable leveling in most places to prepare it for irrigation.

Utilization.—Nearly all the type is tilled and devoted to the production of grain, alfalfa, and other general farm crops and deciduous and citrus fruits (Pl. I, fig. 2). Without irrigation the yields are low to moderate, but with irrigation, the incorporation of organic matter, and blasting of the hardpan they are much larger. In suitable locations the type has proved very satisfactory soil for the growing of citrus fruits, olives, figs, and pomegranates, and its utilization for these crops is increasing. Some of the more intensively cultivated crops receive applications of commercial fertilizer. Organic matter has proved to be the chief need of the soil, and irrigation, thorough tillage, and the breaking of the hardpan are important factors.

MADERA SERIES.

The soils of the Madera series are derived from weathered, unconsolidated, water-laid deposits, composed of varied rock materials. The soils are brown in color, the lighter textured members being light brown or grayish brown and the heavier often slightly reddish brown or chocolate brown. The soils are underlain at various depths by brown or reddish-brown, heavier textured, rather compact subsoils, which rest upon a reddish-brown hardpan at depths less than 6 feet. The lower subsoil and hardpan are frequently somewhat mottled with concentrations of lime. The hardpan is less dense than that of the San Joaquin series. The substratum below the hardpan resembles the subsoil in texture and color and is permeable to roots and water. Locally the hardpan rests directly upon consolidated rock. The soils are low to moderately low in organic matter. Generally the surface is less hummocky than that of the associated San Joaquin soils.

The Madera soils occupy portions of old modified alluvial fans, with gently sloping, undulating, or slightly rolling surfaces. Drainage is good, though a high water table and alkali occur in some small low-lying areas. The soils differ from those of the San Joaquin series in color and content of organic matter and lime.

The Madera series is represented by four groups of soils in this survey, the Madera sandy loams, loam, and clay loams, and the Oakley and Madera sands.

MADERA SANDY LOAMS.

The group Madera sandy loams includes the sandy loam and fine sandy loam types, the former covering 80 per cent or more of the combined area.

Description.—The Madera sandy loam consists of a brown or grayish-brown, medium to coarse textured sandy loam from 12 to 48 inches deep. The soil is locally micaceous and has a friable open structure, readily permeable to roots and water. In the larger areas it is uniform, but elsewhere includes small patches and ridges of sand and occasional areas of loam. Slightly gravelly areas lie near the foothills and along some of the larger streamways, but the stones do not interfere seriously with tillage. The brown color is more intense under moist conditions, and areas adjoining soils of the San Joaquin series usually are reddish brown. Some of this more distinctly reddish-brown material closely approaches in character the San Joaquin soils of similar texture, and it may include some areas recognized as San Joaquin soils in earlier surveys. The soil contains more organic matter than the San Joaquin soils of the same texture,

but responds readily to applications of manure and the growing of cover crops.

In typical areas the subsoil, which is normally more compact and often heavier textured than the surface soil, consists of a brown or reddish-brown heavy sandy loam or loam, resting at a depth of less than 6 feet upon a reddish-brown hardpan, resembling that of the San Joaquin sandy loam, except that it contains occasional seams and crusts of calcareous material. In many places the subsoil is like the surface soil in texture, and the hardpan may be absent, at least within the 6-foot section. This is especially true where the texture at the surface is a light sandy loam or sand. The substratum below the hardpan often resembles the surface soil and is favorable to root development where the hardpan is broken. The depth of soil and subsoil averages much greater than in the same types of the San Joaquin series, which makes the Madera soil usually more desirable for deep-rooted crops. The hardpan lies nearest the surface where the type adjoins the San Joaquin soils. The soil is not ordinarily difficult to till, but is somewhat cloddy in the heavier areas if handled when too wet or too dry. Untilled areas tend to pack and dry out quickly, but when properly cultivated the type is very retentive of moisture.

The Madera fine sandy loam is smooth and friable, and aside from its finer texture possesses about the same features as the sandy loam. It is lower in percentage of coarse material and is sometimes darker in color and higher in organic matter than the sandy loam. In the lower and flatter parts of the type the content of organic matter is higher than elsewhere. In such areas the texture may locally approach a loam. The soil forms a very desirable seed bed if handled under proper moisture conditions, but becomes somewhat compact and hard when dry. It frequently occupies slightly lower levels of more uniform surface than the sandy loam, and is more retentive of moisture if well handled.

Location.—The soils of this group are not so thoroughly weathered as are the types of like texture of the San Joaquin series. The group is confined to the east side of the valley and predominates on many of the upper valley slopes. A large area surrounds Dinuba, and other areas lie west of Sanger, north and east of Reedley, north and south of Clovis, around Fresno, and in the region from Woodlake to Lindsay. The soils are extensive and usually are associated with those of the San Joaquin series; frequently they occupy positions intermediate between the San Joaquin soils and those of the Fresno or Hanford series.

Topography and drainage.—The surface is generally smooth and uniform and in many places requires little leveling for irrigation

(Pl. II, fig. 1), but some areas, especially near the San Joaquin soils, have a hummocky surface, which, though usually less uneven than that of San Joaquin soils, makes some leveling necessary. Along the San Joaquin and Kings Rivers the Madera soils sometimes occur on old terraces. In some localities they occupy low, rounded, or elongated ridges, rising slightly above the general level of the plain. In a few other places small streams have covered portions of the soils with a veneer of Hanford material. Erosion has been most active in the region south of Friant, where small intermittent streams have in some instances eroded narrow winding passages, sometimes 40 feet or more deep, through the otherwise uniform plains. There usually is a deep water table and sufficient slope for good surface drainage. Subdrainage is adequate, except that percolation often is retarded by the compact subsoil layers. Seepage from higher-lying irrigated soils has caused a rise in the ground water in small areas and in some instances has injured crops, either by water-logging the soil or by causing the accumulation of alkali. Some areas of this kind lie south of Fresno. Some of the group is overflowed by Fancher, Red Bank, Dry, and other small creeks, but this has been prevented in part by the construction of levees.

Utilization.—Nearly all the area of this group of soils is under cultivation. Grain and grain hay are the main unirrigated crops. Considerable areas have been brought under irrigation either by pumping or by gravity canals, and in such instances many different intensive crops have displaced the grains. Alfalfa, deciduous fruits, grapes, and truck crops are grown. In most places irrigation improves the vigor of the vines and trees and increases the yields. Water is available for most of the group, and the supply is being augmented by pumping from underground sources. The soils are well adapted to a wide range of crops. Little commercial fertilizer is used, except for citrus fruits. Applications of organic matter give uniformly good results. Where intensively developed the land ranks with the most valuable in the survey.

MADERA LOAM.

Description.—The Madera loam typically consists of a brown or slightly reddish brown loam, which, though low in organic matter, is comparatively friable. Uncultivated areas when dry are compact and hard and when wet extremely boggy. Under field conditions the color is redder than in small hand samples, the reddish cast being still more pronounced when the soil is wet. The soil sometimes extends to the hardpan without marked change in color or texture, but is more often underlain at 12 to 24 inches by a heavier textured subsoil, which may be either a lighter brown or more reddish brown than

the surface material. At depths of 18 inches to 6 feet the brown or red hardpan typical of the series is encountered. Below the hardpan the material is permeable and favorable for root development. The hardpan is often shattered by blasting in preparing the land for the deeper-rooted fruits. The poorest areas of the type are those having thick hardpan near the surface and semicemented layers below the hardpan. Where the drainage is poor, subsoil, hardpan, and the underlying material often contain much lime.

The type as mapped includes small areas of lighter and heavier textured soils. The soil is more friable and lighter on the hummocks and heavier in the depressions. Red soils of the San Joaquin series are in places included in small areas. Separation between these two series is sometimes difficult owing to their merging through reddish-brown transitions. Some of the type is grayish brown in color, as in parts of the areas south of Monson and Orosi, where alkali is present and where the soil merges with the adjacent Fresno loams.

Location.—This type is moderately extensive. The largest areas occur in the region between Dinuba and Venice Hill and southwest of Exeter. Smaller areas occur southeast of Clovis and east and southeast of Minkler. The soil sometimes lies along streamways at elevations slightly lower than the surrounding soils, but often occupies positions similar to the San Joaquin loam. It is confined to the upper slopes of the east side of the valley.

Topography and drainage.—The Madera loam has a gently sloping or slightly undulating surface, locally smooth, but in most places very hummocky. Much of it has been leveled for irrigation and areas so prepared contrast strongly with the natural hog-wallow surface. Drainage is defective in the lower areas, owing to slow percolation through the subsoil and to the accumulation of run-off from near-by soils. The more elevated areas have good surface drainage, but even in these the underdrainage is deficient because of the compact subsoil material. Alkali has accumulated in some of the more poorly drained swales or flats along the lower margins of the type, the concentrations in places being sufficient to prevent crop growth. The soil in most of the alkali areas is not typical Madera loam.

Utilization.—The Madera loam is used for the production of both irrigated and unirrigated crops. Dry-farmed grain and grain hay are produced, but the yields are low. The type normally requires irrigation for fruits and other specialized crops, and this is supplied to an extensive acreage both by gravity canals and by pumping from underground sources. Important plantings of citrus fruits have been made near Venice Hill and in other places along the foothills, blasting of the hardpan being resorted to where it lies at shallow depths. Grapes and peaches are the leading irrigated crops in the

areas outside of the thermal belt. Alfalfa is grown to some extent. The better drained areas are gradually being brought under irrigation, although considerable expense is involved in leveling the land and obtaining irrigation water. Areas affected with alkali and some areas without means of irrigation are used for pasture.

MADERA CLAY LOAMS.

The Madera clay loams group includes the clay loam and the silty clay loam, with certain variations.

Description.—The Madera clay loam consists of a brown, dark-brown, or reddish-brown, sticky, rather refractory clay loam, showing in places a tendency toward an adobe structure. At about 10 to 24 inches the subsoil is encountered, consisting of more compact and slightly redder or lighter brown material. The subsoil rests upon a brown or reddish hardpan at depths ranging from 2 to 6 feet. Both the subsoil and hardpan carry calcareous materials, concentrations being more pronounced in the poorly drained areas, where the hardpan may gradually merge into that typical of some of the other soil series, such as the Fresno. The hardpan varies greatly in thickness and density. Where a distinct hardpan is absent the subsoil is sufficiently compact to interfere with root development and the downward movement of water. The clay loam surface soil occasionally rests directly on the hardpan at depths of several feet, without intervening compact layers, which is one of the variations of the type most favorable to crop production.

The Madera silty clay loam is similar to the clay loam in all except texture.

The group as mapped includes some small flat areas that are darker in color than the typical Madera soils and of clay texture. In the vicinity of Yettem it also includes some reddish-brown or red areas, which represent material of the San Joaquin series. Only a small proportion of the Madera soils is affected by alkali. The affected areas are nearly always grayer and the soil is puddled. An important part of the soils southeast of Yettem and practically all the area south of Exeter constitute a variation which carries alkali, lacks the distinctive brown Madera color, is puddled, and is of lower agricultural value than the typical Madera soils.

Location.—The group is mapped around Yettem as an irregular pronged body, and also south of Exeter, covering several square miles.

Topography and drainage.—The surface of the typical Madera clay loams areas is not greatly different from that of adjacent types of the same and other soil series of the valley plains. It is slightly uneven or hummocky under natural conditions, and rainfall accumu-

lates in the intervening depressions. Considerable leveling is necessary for irrigation. The alkali areas are hummocky and occupy slight depressions or swales, which collect the run-off from higher lands.

Utilization.—The soils of this group lying around Yettem are largely planted to grapes and peaches, grown under irrigation. The alkali areas are largely untilled and devoted to pasture.

Pleasanton Series.

The soils of the Pleasanton series are derived from weathered unconsolidated water-laid deposits, originally having their source in a wide range of rocks in which those of sedimentary origin are conspicuous. They are brown, light brown, grayish brown, or slightly reddish brown in color and at a depth of 12 to 24 inches rest upon heavier textured, somewhat compact subsoils of lighter shades of brown than the surface material. The subsoils typically are underlain at depths of less than 6 feet by a gravelly substratum in which rounded quartzose gravel is mixed in varying proportions with finer material. The soils are low to moderately low in organic matter and do not contain conspicuous concentrations of lime in the subsoil or substratum. The series occupies remnants of old elevated smooth-surfaced terraces and hilly or rolling areas, all which are treeless. The drainage is good. The soils are somewhat mixed, intimately associated with soils of other series, and do not occur in extensive bodies in this survey. The series is represented by two soil groups, the Pleasanton loam and sandy loam and the Pleasanton and Antioch loams and clay loams, undifferentiated.

Pleasanton Loam and Sandy Loam.

The group Pleasanton loam and sandy loam includes mainly the loam and sandy loam of the series, of which the former is the more extensive, and small areas of the Pleasanton gravelly loam and the Corning loam and gravelly loam.

Description.—The Pleasanton loam consists of a brown or light-brown loam, with a depth of 10 to 30 inches. The soil is gritty, of moderately friable structure, low in organic matter, and not very retentive of moisture. Some gravel and bowlders are present. The subsoil is a brown, reddish-brown, or yellowish-brown loam or clay loam which carries little or no gravel. It is seldom more than a few inches in thickness and is underlain by gravelly substrata, which frequently alternate with layers of silty or clayey material. The substrata usually consist of a mass of light-brown or reddish-brown sands and silts in which are embedded varying quantities of rounded or subangular cobbles or bowlders. The gravelly layers are generally

permeable, but are semicemented locally and withstand weathering in exposed positions.

The Pleasanton sandy loam consists of a brown or light-brown sandy loam of medium fine texture, 10 to 30 inches deep. The surface soil differs from that of the Pleasanton loam not only in texture but also in structure, being much more porous and therefore more droughty. The content of organic matter is lower than that of the loam. Tillage is not difficult. The subsoil is a sandy loam or loam, and rests upon substrata similar to those of the loam.

The Pleasanton gravelly loam is similar to the loam, except for the occurrence of gravelly material in the surface soil, which is sufficient in amount to affect tillage. Some areas carry large waterworn cobbles, which are removed before intensive cultivation is undertaken.

The soil in the included areas recognized as the Corning loam is red and fairly friable under moderate moisture conditions, but is compact and flinty when dry and boggy when wet. It varies in depth, but generally grades at 10 to 30 inches into a more compact, less pervious, heavier-textured subsoil, which in turn is underlain by gravelly substrata. The underlying gravelly materials, as in the Pleasanton loam, vary widely in compactness and in the relative quantities of gravel and fine material present. The material representing the Corning gravelly loam is very similar to the Corning loam except that it carries sufficient waterworn gravel in the surface soil to influence tillage.

The various types of this group are not distinct; the members of the Pleasanton series grade into those of the Corning series through reddish-brown transitions, while the gravel-free and gravelly types also merge. The distinct heavy-textured subsoil lying between the soil and the gravelly substrata in the Pleasanton types is less pronounced than in many other parts of the State.

The soils of the group depart from the typical near bodies of the Kettleman series where they sometimes occur as a covering several feet deep overlying the materials forming the latter, and in such situations the soil boundaries are somewhat arbitrarily drawn. The body at Clavicle lies adjacent to soils of the Holland series and includes considerable granitic material. Gritty material is also present where the soils lie in contact with the Kettleman loam.

Location.—The group is inextensive in this survey and occurs as irregular areas bordering the foothills or as old, high terraces along some of the streams. It covers a total of 20 square miles, or 12,800 acres. The principal areas lie in the southwestern part of the survey west of the Kettleman Hills and along the Tule River at Clavicle. Other small areas are mapped south of Cantua Creek, along Los Gatos Creek, and at the base of the Kettleman Hills.

Topography and drainage.—The group occurs on terraces at Clavicle and along the foothills on the west side of the valley. These are generally narrow, elongated remnants of former extensive areas that have been eroded away. The areas in the southwestern part of the survey have a gullied surface not well adapted to tillage or irrigation. The body at Clavicle has a gently sloping surface moderately well adapted to irrigation.

A smaller area in the northwestern part of the survey occupies a remnant of an old elevated stream terrace and has a somewhat even surface, breaking away by sharp descents on all sides. The area north of Little Panoche Creek in the same locality is on a lower terrace, although lying considerably above the present channel of the creek. The body near Minkler is likewise an old terrace, some of which is slightly undulating. The soils lie well above the valley floor and usually possess good drainage in both soil and subsoil, but in some cases the surface is marked by hog-wallow mounds and intervening depressions, which restricts the surface run-off and causes puddling of the soil.

Utilization.—In the southwestern part of the area the group is utilized mainly for pasture. The area at Clavicle is irrigated and used in the production of farm crops. The area near Minkler is utilized in part for citrus fruits, being irrigated with pumped water. Most of the areas are remote from shipping points and because of their limited adaptation, without irrigation, have a low value.

PLEASANTON AND ANTIOCH LOAMS AND CLAY LOAMS, UNDIFFERENTIATED.

Description and location.—The group Pleasanton and Antioch loams and clay loams is mapped in one small area in the northwestern corner of the survey and represents a southern extension of an area previously mapped in the adjoining soil survey of the lower San Joaquin Valley. It consists of brown soils which on the basis of subsoil features represent members of the Pleasanton and Antioch series. Those of brown color but possessing distinct gravelly subsoils or gravelly substrata belong to the Pleasanton series. Those without distinct gravelly substrata but with compact, calcareous, and often heavier textured subsoils are recognized as soils of the Antioch series. The conditions of the subsoil are often mixed and indistinct. The group in the present survey is largely composed of the Antioch loam and the Pleasanton loam, the clay loams were more extensive in the earlier survey. A more detailed discussion of these soils is given in the descriptions of the group Antioch loam and clay loam given in a subsequent chapter.

Topography and drainage.—The topography of the soils of this group is slightly rolling or undulating, with local developments of

a hog-wallow surface. They contrast strongly with the Panoche soils which have smoother surfaces. The drainage is good.

Utilization.—These soils, being unretentive of moisture, are not well suited to dry farming in a region of low rainfall. They are used for pasture.

Antioch Series.

The soils of the Antioch series consist of weathered unconsolidated water-laid deposits, derived originally from a variety of rocks among which those of sedimentary origin appear to predominate. The soils are brown with variations of light brown, grayish brown, or dark brown, the darker colors being associated with the heavier types. The subsoils are typically lighter brown, heavier in texture, and more compact than the surface soils. They contain much line, the content decreasing below the depth of 6 feet. The substratum usually is lighter in texture and less compact than the subsoil.

Soils of the Antioch series occur on old modified terraces or alluvial fans generally lying between residual and recent alluvial soils. Much of the surface is smooth but hog wallows are present in places. Drainage is good as a rule. The Antioch soils differ from the Pleasanton soils in the presence of lime concentrations and the absence of gravelly substrata. The Antioch soils are generally treeless.

The series is represented in this survey by the Antioch loam and clay loam, and by the Pleasanton and Antioch loams and clay loams, undifferentiated.

Antioch loam and clay loam.

The group Antioch loam and clay loam includes the loam, clay loam, and silt loam of the series, of which the first named is the most extensive and the last named of very small extent. The soils as found in this area differ somewhat from the typical as mapped elsewhere.

Description.—The Antioch loam consists of a brown, friable loam of rather silty texture, ranging in depth from 12 to 36 inches. It usually is free from gravel or stones and is low in organic matter. The subsoil is in many places similar to the surface soil in texture and structure; in others, while not often extremely heavy or compact, the material is sometimes slightly more impervious than the surface soil. It may contain smaller quantities of conspicuous calcareous material than typical. The color of the subsoil is generally lighter or more yellowish brown than that of the surface soil. The deeper substrata consist of unconsolidated layers of water-laid material.

The Antioch clay loam closely resembles the loam except in texture. It consists of a brown clay loam of more compact or puddled structure than the loam, with a subsoil of lighter color. The subsoil is more calcareous than the subsoil of the loam and, in general, is more typical of the series as mapped elsewhere in the State.

The Antioch silt loam occurs to a small extent. It is similar to the loam in all features except texture.

Locally small areas of Panoche soils have been mapped with this group.

The Antioch loam and clay loam group represents an intermediate condition of weathering and aging between the typical recent alluvial soils and the old valley-filling soils. The cross section of much of the soils is very similar to that of the contiguous Panoche soils, while the surface configuration is like that of the types derived from old valley-filling materials. Weathering has proceeded sufficiently far to produce distinct differences in texture and structure between the soils of the hummocks and those of the intervening depressions, this being apparent in the patchy nature of the grain growth; but under the conditions of low rainfall not enough time has elapsed since deposition for marked zonal development to take place in soil and subsoil.

Location.—The group occurs in a number of areas, ranging from a few hundred acres to several square miles in extent, lying along the western margin of the survey. The Antioch loam covers about two-thirds of the total acreage of the group. The most extensive areas of these soils lie west of Mendota and east of Oilfields, with others of smaller size both north and south of Oilfields. The group is bordered on its hillward side by soils of the Kettleman series, and on its lower side by soils of the Panoche series.

Topography, drainage, and utilization.—In general outline the topography is of alluvial-fan character, but the material is plainly of older deposition than that of the adjacent Panoche series. The surface is sloping in positions farthest out in the valley, but may be rolling along the hill soils on the west, where streams have diversified the topography. In detail practically all the surface is uneven, with hummocks and intervening depressions, which contrasts strongly with the smooth surface of the recent alluvial fans, some of which have been laid down over the older deposits giving these Antioch soils. Boundaries between the group and the soils of the Panoche series often coincide with the change from hog wallow to smooth surface, but separations are sometimes arbitrary. The general topography is favorable to good drainage, except as the small depressions interfere with the run-off. Practically all the group is capable of tillage and, when leveled, is adapted to irrigation. A small part of the group is used for the production of grain and hay, but the yields are very uncertain, and the soils seem less well suited to dry farming than Panoche soils of similar textures. A number of homesteads have been located on these soils in recent years, and most of the farming at this time is connected with their development. Water for household use is difficult to obtain and in many places must be hauled

several miles. The use of the soils seems to be limited to pasture, hay, and grain growing, or, in a small way, to the production of some of the sorghums.

Porterville Series.

The soils of the Porterville series are derived from old consolidated water-laid deposits, composed chiefly of wash from basic igneous rocks. The soils typically are deep chocolate brown or dark reddish brown in color and contain considerable organic matter. The subsoils are brown, yellowish brown, reddish brown, or grayish brown in color, and are similar to or heavier than the surface soils in texture. Lime occurs in the subsoil as seams or grayish mottlings, the quantity present varying greatly. The substratum resembles the subsoil; no compact or indurated layers occur.

The Porterville soils occupy foot slopes or parts of old fans and have a gently sloping or gently rolling topography. They are well drained and free from alkali. One group of soils, the Porterville adobe soils, represents the series in this survey.

Porterville adobe soils.

The Porterville adobe soils include the clay loam adobe and clay adobe types of the series. The clay loam adobe is the more extensive, occupying 80 per cent or more of the area covered by the group.

Description.—The Porterville clay loam adobe consists of a chocolate-brown or dark-brown heavy-textured clay loam of pronounced adobe structure. It carries varying quantities of rounded or subangular quartzite cobblestones and gravel. The coarse rock material is most abundant in the areas nearest the foothills, and northwest of Redbank and in a few other places forms so large a part of the soil mass as seriously to interfere with tillage.

The finer soil material is quite uniform over most of the type, but small reddish-brown patches, representing the San Joaquin loam, and small areas of dark-gray to black color, in reality Montezuma clay adobe, are included. The color is redder near bodies of the San Joaquin loam, and the boundary between these two types is indefinite in places. The soil is darker colored and very sticky when wet, and bakes hard and becomes flinty upon drying without cultivation.

At a depth of 2 to 4 feet the soil rests upon a brown, reddish-brown, or grayish-brown clay loam subsoil, in many places somewhat lighter in texture than the soil, containing small quantities of coarse, gritty sand or local pockets of gravel or cobble. The subsoil is permeable to roots and water as a rule, but is more or less compact locally, with occasional layers resembling hardpan. The subsoil carries considerable quantities of lime, which frequently give it a marly appearance with definite gray and white mottling in places. The lime is so

abundant in places that it influences the soil structure and causes extreme checking of the surface material, forming a layer of small granular fragments, in areas locally known as "dry-bog adobe." In a few places the subsoil is red to a considerable depth and under such conditions the concentration is apparently much less. The substratum to a depth of many feet often resembles the subsoil in texture and color but it seldom contains such definite concentrations of lime. Occasionally it shows a tendency toward stratification.

The Porterville clay adobe consists of a dark reddish brown heavy-textured clay, of marked adobe structure. The soil sometimes has a darker color when wet and in some cases becomes redder. In places it carries small quantities of gravel and cobblestones, but these do not usually interfere with tillage. It is quite uniform in texture and color over most of its extent, but small areas of Montezuma clay adobe have been included with it in mapping. It is high in organic matter. Though difficult to till, the soil, if handled at the proper degree of moisture, works into a friable, well-granulated seed bed for a soil of its heavy texture. At 2 to 5 feet below the surface the soil grades into a brown, reddish-brown, dark-brown, or grayish-brown clay which is permeable to roots and water. There is a slight tendency toward stratification locally, and varying quantities of lime are present, resulting in some places in a gray mottling and in others in only a lighter color in the subsoil. In places the type does not appear to have reached as advanced a stage in weathering as does the clay loam adobe and concentrations of lime are less marked. The substratum resembles the subsoil except that lime is not so conspicuous below the 6-foot depth. Small quantities of gravel and cobblestones occur locally in the subsoil, mainly near the foothills.

A dark reddish brown clay adobe variation covering about 8 square miles occurs on a mesa or old terrace north of Centerville. This soil differs from the typical in position and in the large quantity of waterworn quartzite gravel and cobblestones present on the surface and mixed with the soil and subsoil. The soil is underlain at a depth of 2 to 6 feet by a heavy loam or clay loam, which is high in lime, and semicemented or loose gravelly layers occur locally at depths of 3 to 6 feet or more. The variation lacks uniformity in color and texture, and includes small spots of reddish-brown or brown loam and clay loam. Tillage is somewhat difficult because of the heavy texture and high stone content, and water for irrigation is hard to obtain. This soil is mapped as the Centerville clay adobe in the earlier detailed survey of Fresno County.

Location.—The Porterville adobe soils cover 70 square miles, and are confined to the east side of the valley. They occur close to the foothills and lie along the eastern edge of the survey from the southern boundary to a point north of Centerville. The clay adobe is

most prominent southeast of Orosi and the clay loam adobe from Lemoncove southward through Frazier and Pleasant Valleys to the southern boundary of the area.

Topography and drainage.—This group of soils has a smooth, uniform surface, and very little leveling is necessary to prepare the land for irrigation. The clay loam adobe is less uniform in surface features, and south of Porterville, east of Exeter, and northeast of Centerville it has a somewhat rolling topography and in places occupies a series of rounded ridges projecting from the foothills and somewhat elevated above the general level of the plains. These soils generally occur as a series of foot slopes around the base of hilly areas and as old eroded fans lying immediately below the Olympic soils, from which they are often derived, and the boundary line between the two series frequently is indistinct. The soils usually have sufficient slope and depth to water table to give them good surface drainage and subdrainage, but some areas are rather flat, as near Seville and elsewhere. Their granular adobe structure enables them to absorb moisture readily. A few of the more nearly level areas become waterlogged during the winter months and bake upon drying, so that they are unfavorable for tree fruits. The clay adobe has a smooth, uniform surface over most of its extent. It is not so well drained as the clay loam adobe. It also has been more subject to reworking by small intermittent streams, and locally resembles the recent alluvial soils in surface conditions.

Utilization.—The group includes some of the more important and valuable soils of the area for the culture of citrus fruits (Pl. I, fig. 2). Grapes and deciduous fruits are grown locally. The land formerly was utilized for grain growing, but is now largely used in the production of citrus fruits because of its favorable slope and protection from frost, as well as high productiveness. Many of the more valuable and productive groves of the area are located on these soils. The methods of handling the soil and the fertilizer practices vary greatly with individual owners. The physical condition of the soils requires much attention for best results with citrus fruits, and seldom receives enough attention. Manure and cover crops have a marked influence on the soil structure, and where properly used make the soil loamy, much better aerated, and more retentive of moisture. Irrigation is essential for citrus fruits. The quantity of water required depends upon the depth of the soil and the thoroughness of tillage. Bearing orchards receive from 3 to 7 applications of water. Young trees are given much more frequent applications, the quantity of water used at each irrigation being smaller than in case of mature trees.

Land values vary greatly and usually range above $100 an acre for undeveloped land with water possibilities.

Fresno Series.

The soils of the Fresno series are derived from old unconsolidated water-laid deposits composed of materials coming from many different kinds of rocks. The soils are gray, brownish gray, or light grayish brown in color, with extensive grayish-brown and brown variations. The subsoil typically is of lighter color and in many places somewhat heavier texture and more compact structure than the surface soils. The subsoil rests upon very compact or cemented silty hardpan layers at depths less than 6 feet. Below the hardpan the material often resembles the subsoil. Both subsoil and substratum usually contain varying quantities of lime, either as gray mottlings, in seams, or as nodules. The soils are low in organic matter but are not difficult to till. The series usually occurs on extensive plains identified with old, modified alluvial fans, and in many places lies between the San Joaquin series and more recent soils along the valley trough. The surface is gently sloping and marked by a number of small sloughways and numerous hummocks. The soils are often poorly drained, owing to their low, flat positions and high water table, and alkali is generally present in harmful quantities. Some areas are well drained. The series is represented in this survey by two soil types, the Fresno sandy loam and Fresno fine sandy loam, each with a phase; by two groups of closely related soils, the Fresno loams and Fresno loams, heavy phase; and by two other mixed groups, the Fresno and Merced loams, undifferentiated, and the Oakley and Fresno sands, undifferentiated.

Fresno sandy loam.

Description.—The Fresno sandy loam typically consists of a light-gray or light brownish gray sandy loam. The soil may be underlain by a heavier textured, more compact, browner subsoil resting on a hardpan, as in parts of the areas along the valley trough southwest of Fresno, or it may rest directly upon a hardpan. Hardpan is typical of the series. It is of grayish color and usually lies at depths ranging from 1 foot or less to 3 or 4 feet below the surface. In exceptional cases there is no hardpan, its place being taken by a compact but unconsolidated layer. The hardpan varies in thickness from thin lenses, in which case it may be intermittent, to very thick, hard and continuous layers. Typically it is sufficiently dense to interfere with the penetration of roots and the movement of water. It may or may not be highly calcareous. The substratum, i. e., the material beneath the hardpan, is variable, and is sometimes stratified, containing material of both lighter and heavier texture than the surface soil.

The Fresno sandy loam varies in color and structure within short distances. The better drained mounds incline to a browner color, while the intervening depressions, in which the soil is puddled, are lighter gray in color, the material being heavier textured than elsewhere. In plowed fields the soil is often well pulverized on the mounds but cloddy in the depressions. Also there are included brownish variations, which resemble the Fresno sandy loam, brown phase.

The Fresno sandy loam grades into the fine sandy loam and loam members of the series. It averages lower in organic matter, has a shallower and denser hardpan, a more puddled structure, and a higher content of alkali than the Fresno sandy loam, brown phase. It is nonmicaceous, except in some of the least modified, younger deposits.

Location.—The largest bodies of the type lie along the valley trough west and south of Fresno. Several small areas lie west and north of Visalia.

Topography and drainage.—In surface features the sandy loam closely resembles the fine sandy loam and loam members of the series. The type occupies plains or flats of slight gradient, with frequent low ridges and belts of flat lands. The surface usually is uneven, being marked by low symmetrical mounds and small depressions, sometimes without outlet or only imperfectly drained. Most of the type is so affected by alkali as to be useless for agriculture unless reclaimed. It has a high water table and naturally imperfect drainage in many situations, and the drainage has been rendered still more unfavorable by the burdening of the subdrainage with seepage water, as a result of irrigation of the upper valley slopes.

Utilization.—A small part of the type is used for general farm crops, such as alfalfa and grain, and locally for more intensive crops, such as grapes and other fruits. These uses are possible only on the alkali-free or slightly affected areas. The larger bodies are used for pasture and are often held in large tracts.

FRESNO SANDY LOAM, BROWN PHASE.

Description.—The Fresno sandy loam, brown phase, consists of a medium to light textured, friable, smooth, open-structured sandy loam ranging in depth from 12 to 36 inches. The color of the soil is brown, light brown, or grayish brown, and the phase includes minor bodies of gray material varying in texture from sandy loam to loam. Some mica is present in places, the amount depending upon the influence and size of small intermittent streams which are locally adding small quantities of fresh material to the surface soil. The soil is retentive of moisture, and, though low in organic matter,

is easily tilled, except in areas of heavier texture and poor drainage, in which case a somewhat cloddy surface may form. The subsoil where typically developed consists of a brown or grayish-brown, more or less compact, heavy sandy loam or loam resting upon compact or cemented silty hardpan layers, which usually serve to check penetration by roots and water. The hardpan varies greatly in depth, thickness, and hardness and is intermittent or entirely absent in places. It ranges from a few inches to several feet in thickness and usually lies at least 4 feet below the surface. The less firmly indurated portions of the hardpan soften when wet, as where irrigation is practiced. The substratum below the hardpan often resembles the subsoil in texture and color and is generally permeable. Little or no gravel is present in the soil or subsoil except near abandoned streamways, where some fine gravel and coarse gritty sand occur. Lime is present in the lower subsoil, hardpan, and substratum, either as seams, nodules, or small gray mottled patches. The areas nearest the valley trough frequently are most calcareous and are more irregular in surface configuration and less favorable for agriculture. The phase includes some small rather flat or slightly depressed bodies of grayer color and heavier texture, which are somewhat compact and puddled and are often covered by shallow ponds during wet weather. These minor areas have shallow soils, compact, heavy subsoils, and a hardpan relatively near the surface. Wind action has slightly influenced the lighter textured areas, and some drifting occurs over exposed surfaces. A part of the phase south of Sanger has a brown or reddish-brown subsoil, which is not so high in lime as that of the more typical bodies. The phase is separated from the typical Fresno sandy loam on the basis of differences in color, drainage, and structure.

Location.—The Fresno sandy loam, brown phase, is confined to the east side of the valley, where it occurs in a number of areas varying greatly in size. It is quite extensive and ranks among the most important soils of the area for intensive crops. It is encountered on the plains and is most prominently developed in Fresno County from Whites Bridge east to Rolinda. Rather large areas extend from near Laton northeastward to Sanger, and it is also prominent in the region around Fowler, west of McMullin, south of Ormus, and near Reedley.

Topography and drainage.—The phase occurs as a part of the gently sloping valley plains, and while the general topography appears very uniform, the surface is marked in places by hummocks and occasionally by the channels of small intermittent streams and segments of old abandoned channels. Its position marks an intermediate stage of deposition by the larger streams entering the valley from the

east and it forms a part of extensive fans formed by them. The surface features are favorable to drainage, except locally in the zone of contact with the grayer soils of the same series to the west. A few slightly depressed flats of grayer color have been included with the phase. These are affected by standing water in wet weather and usually contain larger amounts of alkali than the soil of better drained areas. The subsoil in the deeper parts of the phase favors subdrainage, but in areas approaching the valley trough a rather shallow water table exists. Here the content of alkali is relatively large. The surface is ordinarily suited to tillage, but considerable leveling is necessary in places to prepare the land for irrigation.

Utilization.—Practically all this soil is under cultivation, except in the small areas strongly impregnated with alkali or in those having a high water table. A small part, formerly ranked among the best soils of the area, has been abandoned on account of these conditions, which are directly traceable to seepage from higher lands. A large part is still used for grain, grain hay, and pasturage. More than one-half the phase is intensively farmed. Grapes, peaches, and several other deciduous fruits produce fair returns in favorable locations without irrigation, but the application of water is necessary for best returns with most of the intensive crops and alfalfa. The soil has a very wide adaptation and nearly all crops suited to the climate do well. Such regions are thickly settled and among the oldest, best developed section of the area. The incorporation of organic matter, and good tillage and irrigation are the greatest needs of this soil. Land prices usually range well above $100 an acre for the most desirable parts. Less desirable land brings considerably less. Water for irrigation is available over most of the phase. Some is supplied by gravity canals and some by pumping from underground sources.

FRESNO FINE SANDY LOAM.

Description.—The Fresno fine sandy loam typically consists of a light-gray or light brownish gray fine sandy loam, which is practically free from gravel. The soil puddles slightly or runs together upon wetting, largely because of the alkali which is commonly present. It is apparently low in organic matter. A grayish or brownish compact subsoil of heavier texture than the surface soil sometimes intervenes between the soil and hardpan, as is the case south and west of McMullin; but at depths ranging from less than 12 inches to about 36 inches the soil typically is underlain by the typical gray or brownish-gray hardpan of the series. The thickness and denseness of the hardpan are subject to considerable variation. In some cases it lies at less than 12 inches below the surface, is 2 or 3

feet thick, and is practically impenetrable with a soil auger. In other places it is thin and soft and lies at depths of 4 or 5 feet. It is generally calcareous. The soil material below the hardpan has about the same texture as the surface soil or consists of variable strata, possibly including additional hardpan layers.

The type is characterized by numerous puddled depressions, in which the soil is heavier in texture than that of the intervening mounds. Other variations from the typical occur, such as the sandy streaks or local flats of heavy texture. The development of hardpan is least pronounced in the southernmost bodies of the type, and gives way to compact or semicemented subsoils in some instances. The typical gray color of the soil grades through brownish shades into the brown typical of the phase described below. When dry the soil appears ashen gray in plowed fields, although it is browner when wet.

Location.—The Fresno fine sandy loam occupies several extensive areas and many small ones. The areas south and west of McMullin, north of Laton, around Traver, and north of Goshen are most important. It is associated with other types of the Fresno series, with which it merges, but occasionally is surrounded by recent alluvial soils, from which it may be more readily distinguished.

Topography and drainage.—The larger bodies occupy flattened, gently sloping, or slightly undulating plains on the lower valley slopes. The surface is very uneven, being marked by low, hog-wallow mounds with intervening puddled depressions. Belts of land or slightly elevated ridges occasionally extend for long distances. These surface features contrast strongly with the smooth topography of the recent alluvial soils. Drainage of nearly all the type is naturally deficient, and has been rendered worse by the rise of the ground water through irrigation of higher-lying land. Overflow is not common, but rainfall collects in depressions. Some isolated areas of the soil, slightly elevated above the recent alluvial soils, have a lower water table, but have the characteristic surface and alkali content. Nearly all the soil carries sufficient alkali to make it unfit for agriculture, and the concentration is increasing through evaporation from a high water table.

Utilization.—A large part of the type is used for pasture, with no attempt at cultivation. The worst alkali areas are barren in spots, with only a patchy growth of the most resistant plants. Local areas contain little or no alkali and are farmed successfully, producing such crops as alfalfa, peaches, and grapes. A small part of the type is good agricultural land. The type is often held in large tracts, and where badly affected by alkali and in remote situations it can sometimes be bought for as little as $15 an acre.

FRESNO FINE SANDY LOAM, BROWN PHASE.

Description.—The Fresno fine sandy loam, brown phase, consists of a brown, light-brown, or grayish-brown, smooth, friable fine sandy loam, in places slightly micaceous. It usually ranges in depth from 8 to 36 inches but may continue uniform to 6 feet or more. The soil contains no gravel and is low in organic matter. Where typically developed the subsoil consists of a light-brown or brown fine sandy loam, silt loam, or clay loam, more compact than the surface soil but retentive of moisture and usually permeable to roots and water. At a depth of 2 to 6 feet the subsoil rests upon the typical Fresno hardpan. The material below the hardpan in many places resembles the subsoil. A tendency toward stratification in places gives the phase some variation in the cross section, and several layers of hardpan sometimes occur. Much of the subsoil effervesces freely with acid, and in places a gray mottling, caused by concentrations of lime, occurs.

The Fresno fine sandy loam, brown phase, is variable where it merges with other types, and it includes small bodies of loamy sand, sandy loam, or silt loam. The lightest textured portions drift slightly in exposed positions, giving local areas a slightly undulating surface. It has an open, friable structure but is retentive of moisture. Occasional slight depressions or flats, occupied by the typical gray Fresno fine sandy loam, are included with the phase. In these the soil is puddled and holds water on the surface in wet weather.

Location.—The phase is moderately extensive. It occurs in a number of scattered bodies west of Dinuba, southwest of Fresno, east of Biola, south of Sanger, around Fowler, and west and northwest of Kerman. It is confined to the plains on the east side of the valley and usually lies between areas of Madera or San Joaquin soils and the gray types of the Fresno series farther out in the valley.

Topography and drainage.—The surface of the larger and better developed areas ranges from undulating or gently sloping to nearly flat (Pl. II, fig. 1), and is marked by many low, narrow ridges a foot or two above the general level. Low, rounded hummocks interspersed with flat or basinlike depressions are of common occurrence over the larger bodies. A few small streamways and segments of abandoned channels traverse the phase, but these have little effect on its value for farming. Surface irregularities, unfavorable drainage, shallow hardpan, and alkali usually are more pronounced in the western extension of the phase and near areas of the typical Fresno fine sandy loam than elsewhere. Drainage and alkali conditions vary greatly, but in general are better than in the typical soil. Some areas have been injured by seepage from higher lying soils, and care

in the application of water is necessary to prevent a rise in the water table, which is often less than 20 feet below the surface.

Utilization.—The Fresno fine sandy loam, brown phase, is much less extensive than the typical Fresno fine sandy loam, but is more important agriculturally. The alkali areas are used solely for pasture or are intermittently farmed to grain and hay, with moderate to small yields. The alkali-free and well-drained portions rank among the best soils of the area and are used successfully for grapes, peaches, kafir, and other crops. The moist areas that are free from alkali are often productive without irrigation, but alfalfa and many other intensive crops require irrigation for best yields. Water is obtained both from gravity canals and by pumping from underground sources. The phase is capable of intensive agriculture, especially where water for irrigation is developed, the hardpan broken up, good tillage practiced, and the content of organic matter increased.

The price of land varies widely, depending not only upon soil conditions, such as depth to hardpan, surface irregularities, alkali, and the availability of water for irrigation, but also upon location and state of development.

FRESNO LOAMS.

The group Fresno loams includes the loam and silt loam and heavy phase of these types.

Description.—The Fresno loam typically consists of a gray or brownish-gray loam. It is often compact, puddled or of rather unfavorable structure, this condition resulting from a low organic content, the presence of alkali, and poor drainage. The subsoil is variable, but is in most places mottled, very compact, and heavier textured than the surface soil. In the more poorly drained situations, the subsoil ranges from grayish to dark gray and may be very calcareous, but in better-drained areas it is often friable and browner than the surface material. At depths ranging from 12 to 48 inches the subsoil rests upon the more or less well defined grayish hardpan characterizing the Fresno series. The material beneath the hardpan is often more friable than the subsoil and ranges in color from gray to brown, sometimes mottled.

The Fresno silt loam is of small extent. It differs little from the loam except in texture.

The soils of this group are not uniform, variations in texture, structure, and color occurring within short distances. The hummocks which cover the surface are browner, of lighter texture, and of more friable structure than the intervening depressions. Dark-gray strips of other soils are included. Some of the material in the southern part

of the survey averages light brown in color, and where this is the case the hardpan is less firmly cemented or is displaced by a compact but unindurated subsoil. Variations in structure are sufficient to effect tillage, the most friable soil being easily handled, while that of puddled structure is cloddy and refractory. The body southeast of Tulare merges on the east with soils of the Madera series and is sometimes underlain by the brown or reddish hardpan typical of these soils. Small areas of lighter textured soil are included, some of which are large enough to be mapped separately in a more detailed survey. Some of the soil in sections 7 and 8, between Traver and Monson, is a clay loam in texture, and soils of like heavy texture exist elsewhere, usually where the surface is flat.

Location.—The group, which is extensive, includes several large areas, such as that south and east of Traver, in the Tipton region, and southeast of Tulare. Smaller areas occur surrounded by other soils of the same series and occasionally by soils of more recent origin.

Topography and drainage.—The Fresno loams occupy gently sloping or flat plains which merge gradually into the lower valley slopes. In detail the surface is uneven, having the hog-wallow topography prevalent in the soils of the Fresno series. This tends to restrict surface drainage. Some of the areas receive run-off from higher lying areas and there are strips of puddled soil along many of the winding, indistinct drainage ways. Some areas overflow during rainy seasons, and drainage is in general deficient, owing to overflow, a high water table, or to retarded subdrainage. Practically all the group carry injurious quantities of alkali, and in more than one-half its extent enough to make reclamation necessary.

Utilization.—The soils of this group are largely untilled but are used for pasture. Grain, alfalfa, and the nonsaccharine sorghums are grown locally where the soil is free from alkali or contains only small quantities, but the total acreage of such crops is relatively small and they are confined mainly to marginal areas or included strips of soils.

FRESNO LOAMS, HEAVY PHASE.

Description.—The Fresno loams, heavy phase, consist of a grayish or brownish-gray, compact, fine-textured clay loam, ranging in depth from 8 to 14 inches. The soil in flatter parts frequently is subjected to standing water and in such places is puddled. The color is darker near areas of soil of the Merced series. The more elevated areas are somewhat browner in color and have a more favorable structure than typical. The soil is free from gravel or other coarse material. It is low in organic matter, which tends to make tillage rather difficult unless performed when the soil is in proper moisture condition. The subsoil closely resembles the surface soil in texture and

color and rests at depths varying from a few inches to 3 feet or more upon the typical Fresno hardpan. Below this the material is a gray or grayish-brown clay loam, somewhat similar to the subsoil, in which other hardpan layers may have developed. The soil, subsoil, and substratum effervesce freely with acid, and in places lime appears as white mottles in the subsoil. The soil is rather uniform in texture, but includes a number of small, irregular patches of Merced clay loam, which usually occupy slight depressions or shallow, winding drainage ways.

Location.—The phase covers only a few square miles, occurring in a single area lying north of Corcoran. It occurs well out toward the trough of the valley, between the lighter textured Fresno types and the lower lying, dark-colored soils of the Merced and Foster series.

Topography and drainage.—The surface is very gently sloping to nearly level and smooth, except for small hummocks, depressions, and shallow drainage ways. It does not have sufficient slope for the quick removal of surface waters, and much water is left to evaporate from shallow ponds after the rainy season. The subsoil is often water-logged during the winter months, and subdrainage in general is restricted. The phase has a high water table. Alkali usually is present, but it is patchy and irregular in quantity. In most places the surface requires some leveling for irrigation, but the cost of such work is not great.

Utilization.—The phase is of little importance, and until recently has been used mainly for pasture. Some dry-farmed grain is grown, but yields are low and uncertain. Rice has been introduced recently. Fair yields of this crop are obtained where the soil is well prepared and the crop properly handled. The soil is deficient in organic matter and responds well to applications of manure. Good tillage and irrigation are its chief requisites in growing nearly all crops except grain. The soil is not considered a good one for the production of fruits on account of defective drainage, alkali, hardpan, and frost conditions.

FRESNO AND MERCED LOAMS, UNDIFFERENTIATED.

Description.—The Fresno and Merced loams, undifferentiated, include the Fresno loam and Merced loam as the principal types, with some silt loam and clay loam of both series. The group comprises areas in which the light-gray soils of the Fresno series, and the dark-gray to black soils of the Merced series occur in such intricate association that separation in a survey of this character is impracticable. The included types are described in the discussions of the Fresno loams; Fresno loams, heavy phase; Merced loams, and the Merced clay loams and clays.

Topography and drainage.—The gentle, sloping plains, on which most of the group occurs, are similar in general to those covered by the Fresno loams and Fresno fine sandy loam, but are marked by more numerous shallow waterways. Water from streams of the east side in its course toward the valley trough traverses much of the group by a complex system of shallow channels, many of which are only discontinuous, meandering swales, though a few are well defined. In years of low rainfall only the latter carry water, but in wet years they overflow and modify the intervening soils by gradual reworking or by deposits of fresh material, depending largely on the local gradients. In this manner the Fresno soils are left as slightly higher, more hummocky remnants separated by streaks or flats of the smoother, dark-colored Merced soils. The Fresno and Merced soils occupy different proportions of the surface in different localities, depending upon the degree of stream action. The light-colored soils occupy only small mounds in places and in others predominate or are merely streaked with swales of the other series. Much of the area of the soils of the group could be differentiated in a more detailed survey, but some of the bodies are spotted rather than streaked and include areas which are intermediate in most characteristics between the two series.

Location.—The largest area of these soils is one of irregular outline, centering northwest of Tipton. Others lie west and southwest of Tulare and north of Visalia. Some areas of Merced loams and Fresno loams are mapped within the main areas occupied by this group or around its margins, and the soil boundaries are nearly always rather arbitrary.

The surface features of the group are practically as described under the Fresno loams and the Merced loams. Nearly all the group is affected by alkali, but the quantity present varies widely. Probably more than three-fourths of these soils contain sufficient alkali to prevent crop growth. The Merced soil is often only slightly affected with streaks of alkali and important bodies are alkali free.

Utilization.—The greater part of these soils is used only for pasture. Grains, the sorghums, and alfalfa are grown locally on the better, alkali-free areas, but the production of fruits is negligible. Pumped irrigation water is often supplied and apparently is available for most of the soils. Water for alkali reclamation seems to be the chief need of these soils.

Merced Series.

The soils of the Merced series are composed of somewhat modified, water-laid deposits derived from a wide range of rocks. They are typically dark-gray to black in color and are underlain by brown,

grayish-brown, or gray subsoils similar to or heavier than the surface soils. The subsoil typically carries concentrations of lime, which occur as gray mottlings, seams, and nodules. In places it is compact and only partially permeable to roots. The substratum, that part of the soil section below 6 feet, is generally mottled and poorly drained and similar to the subsoil in color and texture. The soils are high in organic matter. They have a flattened or slightly uneven surface, which is partly overflowed at times. The Merced soils differ from the dark-colored recent alluvial soils in subsoil conditions. Drainage is often defective in wet weather and the water table is high during the winter months, which restricts agricultural development in many places.

The series is represented in this survey by the Merced loams and the Merced clay loams and clays groups, and by the Fresno and Merced loams, undifferentiated.

MERCED LOAMS.

The group Merced loams includes the loam and silt loam of the Merced series.

Description.—The Merced loam typically consists of a dark-gray to black loam which is generally nonmicaceous and free from gravel, grit, or other coarse material. The color is often dark brownish gray, when dry, but becomes darker or even black when wet. The soil when even moderately well drained is fairly friable and easily tilled, but it puddles in the more poorly drained places. It is high in organic matter and often is calcareous. At depths ranging from a few inches to 3 feet or more the soil is underlain by lighter colored subsoils of variable texture, often stratified. The color of the subsoil is brownish where well drained and light gray or mottled where poorly drained; yellowish shades also occur. The subsoil varies greatly in structure. The clayey layers are often very compact and contain much lime, and in general the subsoil is less permeable and more calcareous than the subsoil of the recent alluvial soils. It does not have, however, the distinct layers of hardpan common to many of the old valley-filling soils.

The Merced silt loam has about the same color and structure as the loam. It consists of a smooth-textured silt loam of relatively low silt and high clay content. The subsoil resembles that of the loam except that material of sandy loam and fine sandy loam texture is prominent in much of the large body southwest of Caruthers.

The content of organic matter is very high in situations where the soils have been continuously wet for long periods, and peaty layers are sometimes encountered within the surface few inches or at greater depths. The structure is often affected by the alkali content, which

is usually accompanied by lighter colors and less organic matter. The group in the region south of Tulare and to a less degree elsewhere contains streaks of brown soils which are often of lighter texture and of relatively recent deposition. Some small areas of Fresno soils also are present. These are readily distinguished by their lighter color and more hummocky surface. Parts of the area south of Caruthers contain streaks of recent alluvial soils of both the Hanford and the Foster series.

Location.—The largest area of these soils extends for many miles along the east side of the valley trough from the Kings County line northwestward. Smaller areas lie farther north and others occur on the west side of the trough as near Tranquillity. In this area there is some material of clay loam and clay textures. There are several elongated areas in the region between Tulare and Tipton.

Topography and drainage.—A slightly undulating topography occurs locally, but smooth, gently sloping surfaces broken only by indistinct water courses or shallow sloughs, prevail. Some of the group south of Caruthers was subjected to overflows for long periods before protecting levees were built. Overflow during exceptional seasons covers some of the areas between Tulare and the southern boundary of the survey, but the water here does not remain long. Alkali accumulations have damaged some of the soils to such an extent that they can be used only for pasture. Many of the more important areas are free from alkali or are affected only locally.

Utilization.—Owing to overflow some of the group long remained undeveloped, but over a part of such areas the construction of levees has made tillage possible. Alkali areas and some of those for which irrigation water has not been supplied are used for pasture. Such dry-farmed crops as grain and the sorghums are produced on the better phases. Where irrigated, alfalfa is the principal crop, being grown extensively in connection with the dairying industry.

MERCED CLAY LOAMS AND CLAYS.

The Merced clay loams and clays group includes several of the heavy-textured types of the Merced series, chief among which are the clay adobe, the silty clay loam, and the clay loam adobe. Smaller areas of the clay and clay loam are also included.

Description.—The Merced clay adobe typically consists of a dark-gray to black clay, very sticky when wet and having a pronounced adobe structure when dry. The soil is in many places calcareous and is high in organic matter. Gravel or similar coarse material is rarely present. The dark-colored surface soil occasionally extends to a depth of 4 or 5 feet or more, but is more often underlain at 18 to 36 inches by lighter colored subsoils of grayish or brownish

shades. The subsoil is normally of heavy texture, but may be slightly lighter than the surface soil or contain distinct sandy strata. It is sufficiently calcareous and compact to be less permeable to roots and water than the subsoils of typical recent alluvial soils. The lime concentrations are sometimes sufficient to make the subsoils compact and give them a mottled appearance, although layers of true hardpan are rare. Upon drying without cultivation the soil cracks badly and becomes baked and flinty and untillable, but if cultivated under favorable moisture conditions the adobe tendency aids in obtaining a fair seed bed for a soil of such heavy texture.

The Merced silty clay loam consists of a dark-gray, drab, or black silty clay loam, which extends to a depth of 30 inches or occasionally to 6 feet without marked change. It is quite friable when well handled. In many places the dry, untilled soil has an adobe structure, but when properly handled forms a friable seed bed. The soil is underlain by grayish, yellowish, or brownish subsoils of sticky sandy loam texture, or by strata similar to or lighter or heavier in texture than the surface soil. The subsoil is calcareous and contains nodules or layers of light-colored calcareous material, often not sufficiently dense to interfere seriously with the movement of water or the development of roots.

The Merced clay loam adobe consists of a dark-gray to black clay loam soil, having the same general structural features as the Merced clay adobe except that the adobe structure is less pronounced. In cross section and in the calcareous nature of the subsoil it also resembles the clay adobe, the two types often merging in the field.

The group includes also areas of the Merced clay and the Merced clay loam. They are similar in cross section and in most other features, except structure, to the clay adobe and clay loam adobe.

The soils of the group include some variations from the typical as described above. Some areas of brownish soils are included, and also areas having distinctly friable and not very calcareous subsoils. The latter represent recent alluvial deposits. Where the soils contain alkali they are usually puddled, lighter in color, and apparently lower in organic matter, as in the area lying west of Fresno Slough and extending southward from near Mendota for several miles. A thin overwash of recent alluvium containing mica particles has been deposited locally, and the subsoil often contains strata that are much more sandy and friable than the average. Some areas which in their natural condition were wet for long periods contain peaty layers.

Location.—This group includes the principal soils in the bottom of the valley trough extending from Mendota southeastward for many miles. For much of this distance it occurs on both sides of Fresno

Slough in a strip varying in width from about 1 mile to 8 miles. The soils are interrupted by lighter-textured recent alluvial fan deposits, but occur farther south in another important area. Besides these larger areas smaller areas of the group lie east and southeast of Corcoran.

Topography and drainage.—The soils of the group usually occupy the lowest elevations of their locality and have level, flat, or very gently sloping surfaces without marked irregularities. Some of the alkali land is slightly hummocky with inclosed flats and puddled areas. Shallow waterways are common, and under natural conditions nearly all the group was subject to occasional overflow. Levees have been constructed and now protect much of the land, but the drainage is very sluggish. A high water table prevails, but injurious accumulations of alkali occur in only a small part of the group. The most important area of alkali land is that lying southeast of Mendota, although elsewhere marginal areas and some inclosed spots are affected.

Utilization.—The soils are poorly adapted to fruits and most intensive crops, owing to unfavorable texture, drainage, and frost conditions, although a few small orchards have been planted. Alfalfa is an important crop around Tranquillity and elsewhere, and is grown mainly in connection with the dairy industry. Grain and grain hay are produced, usually with good yields. Rice is grown to a small extent near Corcoran. The alkali areas are utilized for pasture.

Montezuma Series.

The types of the Montezuma series are derived from unconsolidated water-laid deposits which have been considerably changed by weathering, erosion, and other agencies since their deposition. The materials forming these deposits come from sedimentary and igneous rocks. The surface soils are dark gray to black, often with a brownish cast. The subsoil to a depth of 6 feet is grayish brown, yellowish brown, or gray. It contains much lime, occurring as gray mottling or as seams or nodules. The subsoil is as heavy as or heavier than the surface soil and in places is somewhat compact. The soils are high in organic matter, and with good tillage are retentive of moisture. They have a gently sloping, undulating, or rolling topography. Drainage is good, and no alkali is present. The series is represented in this area by the clay adobe.

Montezuma clay adobe.

Description.—The Montezuma clay adobe consists of a dark-gray to black heavy-textured clay of pronounced adobe structure. The soil is very sticky when wet, is well granulated and friable when

tilled under proper moisture conditions, and is free from coarse or gritty material except locally along the foothills, where small quantities of gravel and cobblestones are present. The higher and slightly undulating parts of the type frequently have a brownish cast and gradually merge into the soils of other series. At depths ranging from 12 to 60 inches the soil grades into a gray, grayish-brown, or dark grayish brown calcareous clay or clay loam. The lime occurs in numerous white or gray streaks or in spots often as large as a hen's egg, and in places is present in nodular form or in small lenses resembling hardpan. The lime concentrations usually decrease below 5 feet and give way to a dark-brown or reddish-brown clay. Negligible quantities of gravel and cobblestones are present locally in the subsoil.

In the western part of Frazier Valley small calcareous nodules give the soil a grayish appearance in places. Small included bodies, usually of reddish-brown or red color, as in the bodies east of Clovis, have a distinct hardpan.

Location, topography, and drainage.—The Montezuma clay adobe covers 18 square miles or 11,520 acres, and is principally confined to the Frazier and Pleasant Valleys with smaller bodies along the foothills from near Exeter northward into Fresno County. It occurs only on alluvial fans and footslopes on the east side of the valley. It generally has a smooth, gently sloping surface. There are some gently undulating or rolling areas, but on the whole the surface is less diversified than in much of this soil elsewhere in the State. Some flat areas exist, such as the one north of Orosi. The underground water lies at some depth and there is no danger of crops being injured by alkali. Over most of this type little difficulty is experienced in preparing the land for irrigation, though leveling is necessary in places.

Utilization.—Most of this soil is under cultivation. It is used chiefly for grain growing, the supply of irrigation water being inadequate for other crops. In the region north of Orosi and elsewhere a small part is used for fruits, and yields are good where the supply of water for irrigation is ample, and good tillage is practiced. Very little fertilizer is used except for citrus fruits. Thorough tillage, the addition of organic matter, and irrigation are the most important needs of this soil.

SOILS FROM RECENT ALLUVIAL MATERIAL.

Panoche Series.

The soils of the Panoche series are derived from recent alluvial deposits of gray or light-gray to light brownish gray color and coming principally from sedimentary rocks. The soils are low in or-

ganic-matter content. The subsoils, which are of the same or slightly lighter color, are similar to the surface soils in texture or may consist of strata of varying texture. Hardpan or dense subsoils are not typically present. These soils occupy broad alluvial fans and alluvial valley slopes and small areas of stream terrace and stream bottom. The areas usually have a gentle slope and uniform surface, except for low stream-built ridges and occasional small dunes. Drainage is good except in low, flat, or depressed parts near the valley trough, where seepage and a high water table occur. In such places harmful quantities of alkali may be present. The soils have developed under conditions of scanty rainfall, and are usually treeless, but generally support a low growth of brush and grasses in their native state. The Panoche soils are distinguished from the Laguna soils of similar origin by the high content of lime in the soil and subsoil.

The Panoche series is represented in this survey by four soil groups—the sandy loams, loams, clay loams, and the adobe soils.

PANOCHE SANDY LOAMS.

The group Panoche sandy loams include the Panoche sandy loam and fine sandy loam, the sandy loam predominating.

Description.—The surface soil of the Panoche sandy loam consists of a light brownish gray or gray, nonmicaceous, friable, loose-structured sandy loam, generally showing but little change to a depth of 6 feet or more, except that the color below about 12 inches is lighter. It contains a small percentage of medium-sized gravel along streams and near the foothills. The content of organic matter is usually low, though the soil is receptive of moisture. The subsoil below about 12 inches is in places considerably stratified. In parts adjacent to the low, rounded hills occupied by residual soils the depth of the soil and subsoil is subject to some variation, and the type may be underlain by residual materials. Areas along the upper courses of Little Panoche, Panoche, Los Gatos, Waltham, Jacalitos, and Zapato Creeks are much lighter in texture than typical, and carry large quantities of gravel. Both soil and subsoil are calcareous.

The Panoche fine sandy loam differs little from the sandy loam except in its finer texture. It is generally free from gravel. It often occupies a position between the Panoche sandy loam and the Panoche loam. Most of the areas of the group as mapped contain small areas of the loam.

The soils of this group vary greatly in texture within short distances, being much more streaked than other soil groups of the Panoche series. Some very sandy or gravelly areas that resemble Riverwash are included. Small areas of Panoche sand also are in-

cluded. Some of the more brownish variations, which are generally less calcareous, approach in character soils of the Yolo series, which are of similar origin and of widespread occurrence on the west side of the valley farther north, where the average rainfall is slightly greater.

Location.—The Panoche sandy loams cover a total of 118 square miles, occurring entirely on the west side of the valley. The principal bodies occupy alluvial fans along Panoche, Cantua, and Jacalitos Creeks and around the base of the Kettleman Hills. Large areas are mapped west of Huron, southwest of Tranquillity, and west of Mendota. Smaller areas lie along other creeks and on the valley slopes. Many areas bordering streams extend far out into the valley.

Topography and drainage.—The Panoche sandy loams have the smooth and even surface characteristic of the Panoche series. The group occupies portions of sloping alluvial fans. It often occupies the central or highest part of the fans or of their dividing lobes, and in general lies slightly higher than the other soil groups of the Panoche series. Both surface drainage and underdrainage are good, and in the lighter variations excessive. The areas on the more steeply sloping fans, particularly, are droughty. Water for domestic purposes is difficult to obtain on the higher parts. The surface of the type is favorable for irrigation.

Utilization.—The group is utilized to a less extent than the loams and clay loams of the same series because of its more droughty nature. Dry farming is considered hazardous. The greater part of the group is still covered with "shad scale" and other brushy or desertlike growths. It is used chiefly for pasture, but supports a scant growth of grass. Grain is grown west of Huron by dry-farming methods and some alfalfa is produced where irrigation is developed. Some attempts to grow olives with irrigation have been made on the fan north of the Kettleman Hills.

PANOCHE LOAMS.

The group Panoche loams includes the loam and the silt loam types of the Panoche series, both types being fairly extensive. The former generally occurs near the hills or in the proximity of the lighter textured soils, while the latter is most prominent farther out in the valley near the heavier textured types.

Description.—The Panoche loam is a gray or light-gray to light grayish brown, medium to heavy textured, nonmicaceous loam which may extend to 6 feet or more without change in texture or may be underlain at any depth below several inches by strata of varying texture. The surface soil when dry is grayer and appears of lighter texture than when wet. It is very friable and easily tilled. The

type is more retentive of moisture and higher in organic matter than the Panoche sandy loam. It is slightly gravelly in some localities. The subsoil is generally lighter brown or more yellowish or reddish brown than the surface soil, and ranges in texture from sandy or silty material to a loam or light clay loam. The subsoil averages heavier than that of the Panoche sandy loams, but lighter than that of the Panoche clay loams. The surface soil and subsoil are generally distinctly calcareous. The type is uniform over extensive areas.

The Panoche silt loam is a light-gray or gray to light grayish brown, medium to heavy textured, calcareous silt loam. The subsoil is more often distinct from the soil than in the loam. At about 24 to 36 inches it usually shows a more pronounced brownish tint and a slightly more compact structure. In many places it is a yellowish-brown silt loam or silty clay loam, but is always readily permeable to roots and water. The silt loam has a somewhat higher organic-matter content than is typical of the loam. The two types are much alike in many features.

Both soils in this group have a powdery structure when dry, which sometimes gives them the appearance of soils of lighter textures. When thoroughly wet they are sticky, but little puddling occurs. While the soils are generally uniform, there are local variations in texture, topography, structure, and content of organic matter and gravel. Small areas of hummocky nature occur on the plains southwest of Huron and elsewhere, resulting either from wind action or erosion. Near the trough of the valley the group has some of the subsoil characteristics of older soils, and small areas of modified alluvial soils are included. Some of the included material has a brownish color and is less calcareous than the more typical gray soils. Such areas approach in character the soils of the Yolo series, which have a similar origin and mode of occurrence. The substratum of the Panoche loams group is somewhat streaked and mottled with calcareous material in places of greatest age or where the soils are derived from areas of sedimentary rocks high in such material.

Location.—The Panoche loams group is one of the extensive groups on the west side of the valley. The principal areas occupy an interrupted belt along the upper valley slopes, at the foot of the mountains, and extend for several miles toward the center of the valley, in several places nearly to its trough.

Topography and drainage.—The Panoche loams occur on alluvial fans and low, broad stream-built ridges. The slope is greatest near the hills and decreases toward the valley trough, where it is very gentle. The surface in detail is slightly undulating or smooth, with small included flats or slightly depressed areas locally poorly drained

and affected with alkali. The surface of the group is typically smooth and well suited to cultivation and irrigation. The lower extensions of the areas have a slightly higher elevation than the heavier textured adjacent types, but a somewhat lower average elevation than the Panoche sandy loams. The Panoche loams are well drained as a rule and areas of high water table or alkali accumulation are small and confined to the region near the trough of the valley.

Utilization.—The soils of the group are treeless, but locally have a scattered growth of low brush. They are well suited to a wide range of intensive crops, but the low rainfall and the difficulty and expense of obtaining irrigation water combine to restrict their use. Most of the land is used for pasture. Dry-farmed crops consist almost exclusively of grain and the nonsaccharine sorghums, the latter on only a small acreage, and even these crops frequently fail completely. In wet years with well-distributed rainfall profitable yields are obtained. A widely fluctuating acreage is farmed, the area planted to crops being influenced by periods of wet and dry seasons, but the average area planted is but a small percentage of the total area of the group. Little irrigation water, either from underground sources or from streams, is available. Small quantities of water, obtained from wells along Waltham and Jacalitos Creeks are used to irrigate a small acreage in these neighborhoods. Other wells are being developed farther north on the plains. Flood waters from the larger creeks are often diverted for irrigation, but this supply is only available for short periods and is not dependable. The favorable character of these and adjacent soils has stimulated plans for the development of irrigation.

Much of the group lies remote from transportation facilities and the land can often be bought for as little as $25 an acre. The difficulty of obtaining water even for domestic purposes tends to depress the price of land of this group.

PANOCHE CLAY LOAMS.

The group Panoche clay loams includes the clay loam and the silty clay loam types, of which the latter is probably the more extensive, although both types are among the more extensive soils of the survey.

Description.—The soil of the Panoche silty clay loam is a gray to brownish-gray silty clay loam, 18 to 24 inches in depth. It is sticky and rather compact when wet, but is friable and pulverizes easily when handled under proper moisture conditions. Its structure varies, being most favorable to tillage where the slope is sufficient to give good drainage, and least favorable in flats or slight depressions where water stands in wet weather, as in areas nearest the valley

trough. A tendency toward an adobe structure occurs locally in the flatter positions and where the content of organic matter is greatest. The type contains more organic matter than the lighter textured soils of the series, and is more retentive of moisture and better suited to dry-farmed crops. Little gravel or other coarse material is present. The soil is often uniform throughout large areas. The subsoil is light gray or yellowish brown in color, and is similar to the soil in texture and structure to a depth of 6 feet or more or consists of layers of sandy or silty material with local concentrations of lime. Both the soil and subsoil are calcareous. The substratum resembles the subsoil to great depths. Commonly there is no distinct line of demarcation between the soil, subsoil, and substratum, but some of the type of oldest deposition shows the effects of age, as indicated by occasional compact, poorly structured subsoils which, however, do not seriously interfere with root development or the movement of water. The cross section of the type sometimes shows varying quantities of gravel in the subsoil and substratum.

The Panoche clay loam differs little from the Panoche silty clay loam except in texture, having a somewhat greater proportion of clay and a lower silt content. Where the type merges with the lighter types of the series it contains more coarse material and possibly less organic matter.

Boundaries between this group and other soils on the valley slopes frequently are indefinite, and gradations from lighter to heavier textures occur. Some local variations, which differ slightly from the main type in color, organic-matter content, structure, or surface configuration, are included. Near the trough of the valley the typical color gives way locally to the darker colors of the Merced or Sacramento series while the texture also often becomes heavier, the content of organic matter is higher, and the structure more puddled or adobe-like. In some of the browner variations the material is less uniformly calcareous, and approaches in color and character the related soils of the Yolo series, which are of brown color and of similar origin and mode of occurrence. Some of the included material may in such localities represent the grayer variations of the Yolo soils.

Location.—The Panoche clay loams are extensive in this survey, covering 438 square miles, or 9.8 per cent of the area surveyed. They occur only on the west side of the valley and extend almost continuously from the northern to the southern boundary of the area. Nearly all the group is contained in one large, irregularly shaped body which occupies a position between the Panoche loams and Panoche sandy loams of the higher valley slopes and the soils of the Merced and Sacramento series in the trough of the valley. A number of smaller areas occur along the lower slopes of the Coast Range foothills.

Topography and drainage. The greater part of the group occupies a uniform, gently sloping plain; the remainder lies on alluvial fans of moderate slope near the foothills. The larger areas occupying the smooth plains are somewhat lower and more regular in surface features than the Panoche loams, and require little leveling for irrigation. The part of the group having greatest slope and elevation is well drained. About one-half of that on the lower valley floor has defective drainage and contains injurious accumulations of alkali. (Pl. II, fig. 2.) The parts affected by alkali lie near the valley trough, and include flat or slightly depressed spots which are covered with shallow standing water during wet weather. Overflow from some of the small drainage ways affects small parts of the group but is never serious.

Utilization.—The Panoche clay loams are not extensively farmed, probably more than 75 per cent of the soils being untilled and used for pasture. They support a sparse growth of brush and grass and, locally, alkali vegetation. The shad scale is less abundant than on the lighter textured soils. With summer fallowing grain yields moderately well in years of favorable rainfall, but dry farming is hazardous. Yields are better than on the lighter types of the Panoche series. Some inextensive areas are irrigated with water pumped from wells. Alfalfa, grain, and the nonsaccharine sorghums are the principal irrigated crops, but the expense involved in supplying water from deep wells is great. The soil conditions are favorable for the production of a wide range of crops, but irrigation is necessary to insure profitable yields.

PANOCHE ADOBE SOILS.

The group Panoche adobe soils includes the clay loam adobe and clay adobe, of which the former probably is the more extensive. The types are often so closely associated that separation is impracticable, the lighter usually occurring on slight elevations and the heavier soil in shallow swales or in flats.

Description.—The Panoche clay loam adobe consists of a gray to brownish-gray, compact heavy clay loam of adobe structure, with a depth of 24 to 30 inches. The color is generally darker than that of the lighter members of the series. The soil is very sticky when wet and cracks deeply and forms rough cubical fragments on drying. A good surface mulch can be maintained by tillage, and the water-holding capacity is high, but the type occurs in regions of low rainfall and is too droughty. A moderate to large percentage of organic matter is usually present, which aids in retaining moisture. Surface water is absorbed freely when the soil structure is open and cracked, but when the soil is wet moisture moves slowly through it.

Cultivation is difficult, and the soil puddles unless handled under proper moisture conditions. The subsoil is a light-brown or slightly yellowish brown silty clay loam, clay loam, or light clay. The structure is compact, but not sufficiently so to interfere with the penetration of roots or water. The soil and subsoil are typically calcareous, and the type sometimes shows calcareous seams or grayish discolorations, due to lime, especially where poorly drained. The substratum differs little from the subsoil to great depths, but in places contains waterworn gravel.

The Panoche clay adobe differs from the clay loam adobe mainly in its slightly greater content of clay.

Portions of the group vary from the typical. The area in the northwestern part of the survey is the southern extremity of a larger area lying to the north and included in the lower San Joaquin Valley survey. It includes spots of lighter texture where it merges with the Panoche clay loams group, and the texture may approach a loam over small areas, while some gravel is present. A part of this area resembles the old valley-filling soils in being somewhat hummocky and having somewhat more compact subsoils. The southernmost area on the west side of the valley does not exhibit the adobe structure to a marked degree. As is the case with the other soils of this series, the group as mapped includes some soils of quite pronounced brownish tint, which closely approach in character the related Yolo soils, into which the Panoche soils merge gradually.

Location.—Several areas of this group are mapped, but the soils are of greater importance north of the present survey. In addition to the area northwest of Mendota an area lies southwest of Lethent and one of very small size about 5 miles south of Tranquillity. The group covers an area of 10 square miles.

Topography and drainage.—The Panoche adobe soils typically have a gently sloping or nearly level, smooth surface, but irregularities occur locally. The surface is readily fitted to irrigation, some leveling being necessary in the more undulating areas. Drainage is not so good as in the case of the lighter textured types of the series, owing to the slight slope of the surface and to the accumulation of run-off from higher lying soils. The body at Lethent is only moderately well drained, and a part of it has a high water table and contains accumulations of alkali, which is true also of some other small tracts. Water sometimes stands for short periods in depressions between the hummocks of hog-wallow areas, and in some other places in wet seasons, owing in part to the slowness with which it percolates through the soil.

Utilization.—The Panoche adobe soils can be handled successfully only within a narrow range of moisture conditions. A part of the area northwest of Mendota produces grain, while the area southwest

of Lethent is in pasture. Grain yields well where it has sufficient water, but the low rainfall and difficulty of irrigation tend to restrict the use of the group to pasture. With irrigation the soils are capable of producing alfalfa, rice, and many other crops. They are, however, distinctly less valuable for fruits than the lighter textured soils of the same series.

Laguna Series.

The Laguna soils are derived from recent alluvial material washed mainly from light-colored soft, or partly indurated, sedimentary rocks. The soils are gray to brownish gray in color with minor variations of light grayish brown. They are low in organic matter, but retentive of moisture. The subsoils are gray to brown and either similar in texture to the surface soils or consist of alternating or interbedded strata of varying textures. The series is distinguished from the related Panoche series on the basis of lower lime content, and from the Hanford and Foster series on difference in color. They occupy alluvial fans and stream bottoms and have a smooth to slightly hummocky surface.

One group of soils of this series, the Laguna loam and sandy loam, is mapped in this survey.

Laguna loam and sandy loam.

The group Laguna loam and sandy loam includes the loam and sandy loam, and small areas of the fine sandy loam of the series. The two main types are about equal in extent.

Description.—The Laguna loam consists of a light-gray, ashen-gray, or slightly brownish gray powdery loam. When wet it is sticky and browner in color, resembling the slightly less grayish soils of the Panoche series. It is extremely friable and apparently low in organic matter, though fairly retentive of moisture. The soil as a rule does not carry sufficient gravel to interfere with cultivation, but light-colored, flat shale fragments are common. Some gravelly streaks lie along the streams, and the content of gravel also increases near the hills. The soil sometimes extends with little variation to depths of several feet, but strata of sandy, gravelly, or silty material usually occur below 12 inches.

The Laguna sandy loam is friable, and has about the same range in color, gravel content, and profile as the loam. It is slightly less retentive of moisture than the loam and is more often underlain by coarser material. The Laguna fine sandy loam is of little importance. It has the general characteristics of the other soils of this group.

The loam member usually occupies the more gentle slopes or swales, while the sandy loam lies on the upper slopes or stream-built ridges. The higher parts merge with the Arnold sandy loams.

Location.—The group is confined to one area near the western margin of the survey southwest of Mendota, covering about 25 square miles. It closely resembles the Panoche loams in mode of occurrence. Grayish-brown areas both to the north and to the south are included. These are undifferentiated areas of the Panoche loams or of the Panoche sandy loams.

Topography and drainage.—The soils of the group occupy alluvial fans, the slope of which, along the hill line on the southwest, is rather steep, but decreases toward the valley. The soil area is composed of numerous small coalescing fans, the crests of which are occupied by intermittent streams. The surface is somewhat rolling, with depressions and ridges lying at right angles to the line of the hills. Wind action has modified the surface slightly in some of the bodies of earlier deposition. Drainage is good to excessive. Occasionally the small streams overflow over the fans. Practically all the group is well adapted to tillage and to irrigation, where water can be made available.

Utilization.—The group has not been farmed continuously, and only a small part is tilled. A number of homesteads have been located on these soils, and dry-farmed grain is being produced in scattered plantings. Yields are light and uncertain, and that dry-farmed crops can be grown profitably on these soils has not as yet been demonstrated. With exceptionally heavy or well-distributed rainfall grain and some of the sorghums give moderate yields. The group is used largely for pasture. The soils are remote from transportation facilities, and water for domestic use is difficult to obtain. The soils are treeless and shrubless, except for a sparse growth of shad scale. The price of land of this type is usually low.

Hanford Series.

The soils of the Hanford series are derived from recent alluvial deposits, coming mainly from granitic rocks. They are brown, with variations of grayish-brown and buff colors. They are micaceous and friable, have a medium to low content of organic matter, and are easily tilled and retentive of moisture. The subsoils may resemble the surface soils in color and texture or may be lighter brown, and consist of strata of differing textures. The series occupies gently to moderately sloping alluvial fans or valley slopes, stream bottoms, and deltas. The surface is uniform and smooth except locally, where streams have produced slight irregularities. Drainage is good or defective, depending upon the position of the soil. Seepage, a high

water table, and harmful accumulations of alkali prevail in many places. The series is distinguished from the related Foster soils on the basis of its lighter color and lower organic-matter content. Areas along streamways support a growth of oak, willow, brush, and vines, and oaks are often abundant over the alluvial plains.

The series is represented in this survey by four groups or types of soils—the Hanford sands, Hanford sandy loam, Hanford fine sandy loam, and the Hanford loams.

HANFORD SANDS.

The group Hanford sands include the fine sand and sand of the Hanford series, with small undifferentiated areas of other soils of the series. The fine sand is the most extensive, comprising about 75 per cent of the group. Small areas of coarse sandy material which if more extensive would be recognized as Riverwash, are also included.

Description.—The Hanford fine sand consists of a brown, or grayish-brown, micaceous, open-structured fine sand carrying a moderate to small percentage of organic matter. It is browner and also appears more loamy when wet. Patches and narrow strips along stream bottoms near the foothills often contain gravel. On the plains the subsoil is generally similar to the surface soil. In stream bottoms it is variable, and usually consists of layers of sand, fine sand, silt, or gravel without regular arrangement. The type is retentive of moisture for a soil of its light texture, and is easily tilled.

The Hanford sand is generally lighter brown than the fine sand, and is more porous and lower in organic matter. It is micaceous and where situated in stream bottoms is often flooded, which causes considerable variation in texture, with frequent strips and strata of gravelly material. The plains part of the type is more uniform in profile and the surface is modified locally by wind action. This type is less retentive of moisture than the Hanford fine sand, but closely resembles it in many respects.

The group as mapped includes a gravelly variation of the Hanford sand. This occurs as a belt about one-half mile wide extending from Lanes Bridge on the San Joaquin River, northeast to Friant, a distance of about 6 miles. Two other small areas lie north of Kerman along the San Joaquin River. The variation occupies low terraces between the upland soils and the San Joaquin River bed. It resembles the sand member in many features except that parts are slightly reddish brown and have a loose gravelly substratum several feet below the surface. In places the soil grades into a yellowish-brown, compact sand at a depth of about 4 feet. The gravel is fine and waterworn, and derived from metamorphic and volcanic rocks. The con-

tent of gravel is variable and is sometimes sufficient to interfere with tillage. This variation is well drained and free from alkali, but porous and droughty.

The included bodies of coarse material recognized as Riverwash consist of coarse, light-colored, rather clean sand and waterworn gravel mixed in varying proportions, often interstratified with or covered by minor layers of finer material. The material occupies relatively low, flood-swept positions, and is generally leachy and incoherent, although sometimes water-logged because of its low-lying position.

Location.—The Hanford sands, which are inextensive, usually occur in small areas along the San Joaquin, Kings, Kaweah, and Tule Rivers or occupy slight ridges over the valley slopes, as about Hanford. They occasionally lie in abandoned stream channels, as southwest of Porterville. The most conspicuous body occurs along Kings River northeast of Sanger. The group is confined to the east side of the valley, the soil material in most instances having been transported long distances. The included areas of Riverwash occur as several small areas in bends of the San Joaquin River along the northern margin of the area and as another body along the Kaweah River east of Woodlake. There are several narrow areas which because of their small size are included with the adjacent recent alluvial soils.

Topography and drainage.—The soils of this group have a varied surface. In stream bottoms they are marked by winding channels and are modified by overflow. Areas lying on low terraces usually have a smooth surface, but those on the uplands, which usually occupy low ridges sometimes several feet above the level of adjacent soils, have a surface more uneven. The irregularities, however, are not often pronounced and only rarely is the cost of preparing the land for irrigation high. Both surface drainage and subdrainage are good except in some of the lowest lying areas. In these some alkali has accumulated. The sand has excessive subdrainage in places and is less desirable for the production of fruits, unless an ample supply of irrigation water is available.

Utilization.—Near stream courses the soils of this group support a moderate to heavy growth of willow, brush, and vines. About one-half the total area is utilized for crops, the remainder being in pasture. Deciduous fruits, grapes, truck crops, alfalfa, grain, and kafir are the principal crops. The yields vary with the depth and uniformity of the soil, alkali conditions, and supply of water for irrigation. Areas in stream bottoms are not selected for early blooming fruits on account of frost. The soils are easily handled and respond to the addition of organic matter. The small areas of coarse material representing Riverwash are practically nonagricultural be-

cause of the occurrence of overflow. The most exposed bodies are barren of tree growth, but some areas support a growth of cottonwood, willow, brush, and vines.

The price of land composed of the Hanford sands varies greatly, and depends upon location, water supply, cost of clearing and leveling, freedom from alkali, and uniformity of the soil.

HANFORD SANDY LOAM.

Description.—The Hanford sandy loam consists of a brown, grayish-brown, or buff, friable, micaceous sandy loam extending to depths ranging from 12 to 72 inches. The soil nearer the larger streams is usually of lighter color and of more variable texture than in areas lying farther away. Greater uniformity also exists in the areas removed from overflow conditions, where there may be little variation in the material to a depth of 6 feet or more. The subsoil below 12 inches in stream-bottom areas consists of strata varying widely in texture and generally of slightly lighter brown color than the surface soil. Both soil and subsoil are relatively free from gravel, except in some strips along stream courses near the foothills. The soil contains a moderate to small percentage of organic matter and is easily tilled. A part of the type occurring west of Laton, in the region around Visalia and west of Porterville, includes patches of dark-brown soil which if more extensive would be mapped with the Foster series.

In a shallow variation of the type over a part of the plains west of Laton the soil rests upon material of the older soils of the Fresno and Merced series. The variation differs from the typical in subdrainage, alkali content, and the occurrence of heavy subsoils within the 6-foot section.

Location.—The Hanford sandy loam occurs in many small bodies scattered over the east side of the valley, the type usually being associated with other recent alluvial soils. The principal bodies lie along the San Joaquin, Kings, Kaweah, and Tule Rivers or their distributaries. It often occupies slight elevations on the alluvial fans or lies in old abandoned stream channels.

Topography and drainage.—The surface is smooth or slightly undulating and is occasionally marked by shallow waterways. A growth of willow, vines, and brush commonly occurs near streamways; much of the type originally supported a growth of valley oak. A part of the type occurs on distinct terraces along the larger streams, and in such places the soil is generally uniform and easily prepared for irrigation. The type has good surface drainage, but subdrainage is locally restricted with accompanying accumulations of alkali. The greatest concentrations of alkali are confined to the upper 2 feet of

soil where the subsoil is of light texture, but heavy subsoils may carry considerable quantities. The alkali-affected areas are distinguished by a growth of salt grass and by surface incrustations.

Utilization.—This type is of small extent. Some areas are rather droughty and, with the alkali areas, are used for pasture. The most favorable parts are nearly all under tillage and good yields of alfalfa and of many fruits are obtained. Areas badly affected with alkali require reclamation before profitable crops can be grown. Practically no fertilizers are used, except small quantities of manure. The soil and subsoil are permeable and favorable to deep root penetration. Irrigation is not needed in some of the moist situations. Alfalfa and intensive crops usually require irrigation where drainage is more thorough.

Land prices vary widely, depending on drainage, alkali, and irrigation conditions and on location with respect to shipping points.

HANFORD FINE SANDY LOAM.

Description.—The Hanford fine sandy loam to a depth varying from 12 to 72 inches consists of a brown or grayish-brown, smooth, friable, very micaceous fine sandy loam. In many places the texture closely approaches a fine sand. The color is frequently somewhat darker than the typical and is very nearly dark brown. This is true in the Visalia region and elsewhere, and separation of such variations in the type and associated soils of the Foster series is difficult. The soil contains a moderate to low percentage of organic matter in its more uniform bodies, but those parts having a darker color are higher in this constituent. The soil is often remarkably uniform in texture, and no gravel is present except in places near the foothills. Below a depth of about 12 inches the subsoil is frequently lighter brown, and is often stratified with beds of sand, sandy loam, or silt, which sometimes contain gravel near the foothills. The type is very easily tilled, absorbs and retains moisture well, and responds to applications of organic matter. A relatively shallow variation of the type occurs on the Tule River bottoms west of Porterville as an overwash several feet deep, covering material of the older soils of the San Joaquin or Fresno series. This variation, which covers several square miles and is of considerable importance, corresponds with the more typical areas in all respects except the heavy nature of the underlying material with its local areas of hardpan.

Location.—This type is very extensive, covering an area of 384 square miles. It occurs in extensive areas on the Kings River delta west of Laton, in the Hanford region, and on the river bottoms east of Sanger. Other important areas are mapped around Visalia and along the bottoms of the San Joaquin, Kings, Kaweah, and Tule

Rivers. The type is confined to the east side of the valley in this survey and usually is associated with the courses of the main streams or their distributaries.

Topography and drainage.—The surface is uniform and smooth or slightly ridged, except in proximity to streams, where it may be undulating or traversed by a series of shallow drainage ways often carrying flood waters in the winter and spring. Such waterways have a marked influence upon the soil, and often give rise to variations in both topography and texture. The gradient as a rule is sufficient to afford ample surface drainage, but a high water table, accompanied by the accumulation of alkali, occurs in low-lying situations. The alkali is usually confined to the upper 2 feet of soil unless the subsoil is of heavy texture. Reclamation by drainage, which is facilitated by the favorable texture and structure of the type, has proved successful in places. There is little necessity for leveling either for crops or for irrigation, except where stream action has been most active.

Utilization.—About 75 per cent of the type is under cultivation. It is utilized in the production of a wide range of fruit, truck, and general farm crops. Most of the untilled part is too strongly impregnated with alkali to be farmed. This, with small areas along river channels which are flood swept in times of high water, is used for pasture. The type originally supported a growth of valley oak over most of its extent, with a denser growth of willow, brush, and vines along the streams. The alkali areas support a growth of salt grass. Grapes, peaches, apricots, prunes, melons, and many other truck crops, alfalfa, the sorghums, and grain are the main crops. Good yields of all these crops are obtained. Irrigation is required for many of the crops in the more thoroughly drained situations, but is not necessary in the low moist places.

This soil is one of the most important of the area, and is a heavy producer of highly specialized crops. Manure and cover crops are used for soil improvement, but little commercial fertilizer is applied except in growing certain truck crops. The price of land is variable, but is usually considerably more than $100 an acre for the more desirable land.

HANFORD LOAMS.

The group Hanford loams includes the loam and silt loam members of the series. The latter soil is inextensive.

Description.—The Hanford loam consists of a brown or grayish-brown, friable, smooth, micaceous loam, practically free from gravel or gritty material, and from 12 to 72 inches deep. The soil is grayer near soils of the Fresno series and in slight depressions, and merges gradually with the darker colored Foster and Chino soils. The tex-

ture varies somewhat, being heavier in the lower areas and in places slightly more sandy on small elevations. The soil profile is most uniform in the smoother parts of the type, on the alluvial fans, and least uniform along small streams and distributaries, where periodic overflow occurs. In such areas the subsoil below about 12 inches in many instances consists of sandy, silty, or gravelly strata. The subsoil is generally somewhat lighter brown than the surface soil. Near streams the substratum, that is, the material below 6 feet, usually resembles the subsoil, but sometimes it consists of much older and more compact deposits. The spots of heavier or lighter textured soils included have little general influence upon tillage. The type usually contains more organic matter than the lighter textured soils of the same series.

The Hanford silt loam consists of a smooth, friable, micaceous silt loam, having about the same range in color and the same subsoil features as the loam.

Location.—The Hanford loams cover only a few square miles. They occur in several small areas east of Hanford, and in other isolated areas, such as those west of Visalia, west and southwest of Hanford, and east of Orosi. They are not easily distinguished from adjacent recent-alluvial types.

Topography and drainage.—These soils resemble other members of the Hanford series in general surface features. They occupy slightly lower positions than the types of lighter texture and are often inadequately drained and affected with alkali. Wherever the soils overlie older and more compact deposits, as east of Hanford, they are more subject to the accumulation of seepage water, and frequently require drainage and reclamation before profitable crops can be grown.

Utilization.—More than one-half the area of the group is now uncultivated because of alkali. Such land is used only for pasture. The more desirable land produces fruits, alfalfa, corn, and grain. The yields are high wherever drainage is well established and proper care given the crops, but locally they are low and uncertain.

Prices of land of this group vary greatly, and depend largely upon drainage and the amount of alkali present. The moist areas are farmed successfully without irrigation, but satisfactory returns in other areas are obtained only with irrigation.

Foster Series.

The soils of the Foster series are derived from recent alluvial deposits, coming mainly from granitic rocks. They are dark brown or dark grayish brown in color, high in organic matter, micaceous, friable, easily tilled, and retentive of moisture. The subsoils are brown, grayish brown, or dark grayish brown, and either resemble

the surface soil in texture or are composed of widely variable strata. The series occupies gently sloping alluvial fans, delta plains, or stream bottoms, frequently occurring in slightly depressed, irregular belts extending through areas of the Hanford soils. The surface is smooth and quite uniform. The drainage conditions and alkali content vary, depending upon topographic position and underlying material.

The series is represented in this survey by the Foster sandy loams, and by the Chino and Foster loams, undifferentiated.

FOSTER SANDY LOAMS.

The group Foster sandy loams includes the fine sandy loam, sandy loam, and coarse sandy loam of the series of which the first two predominate and are about equal in extent. Some small areas of similar Hanford soils of similar textures are included.

Description.—The Foster fine sandy loam typically consists of a dark-brown or dark grayish brown, friable, micaceous fine sandy loam, generally free from gravel. It is apparently higher in organic matter than the Hanford fine sandy loam and typically darker in color. The subsoil, which is encountered at depths ranging from 12 to 24 inches, is lighter colored than the surface soil and varies in texture. In places a fine sandy loam texture continues to a depth of 6 feet or more, but strata of different textures are common. The subsoil is friable and easily penetrated by roots and water and typically does not contain concentrations of lime.

The Foster sandy loam consists of a dark-brown or dark grayish brown, micaceous sandy loam, having about the same variations in the subsoil as the fine sandy loam. The coarse sandy loam, which occurs on ridges or along abandoned stream courses, is inextensive. It has coarse-textured subsoil and on the average is less retentive of moisture than the other types of the group.

The Foster sandy loams include many important variations. One consists of areas where the sandy material has been deposited as overwash upon older, more modified deposits. In such places the subsoil may be compact and calcareous. The areas in proximity to the main washes on the upper valley slopes often have more gravelly or sandy subsoils than the average, and the soil section in general is more uniform in regions of gentle slope and near the valley trough. The included soils often occur in narrow strips, intricately associated. The Foster and Hanford soils merge gradually through wide transition zones of intermediate colors, so that separation is difficult and often arbitrary, and areas of each of these series as mapped may include material of the other. The extensive body of the Foster sandy loams mapped in the Tulare and Visalia regions contains frequent small areas properly belonging to the

Hanford series. A large part of the group in the vicinity of Corcoran and northwestward has a peculiar grayish color when dry, but is darker when wet.

Location.—This group is the eighth in extent in the survey. It occurs in association with the Hanford soils on the recent alluvial fans of the Kaweah and Tule Rivers and to a less extent on the Kings River fan around the margin of Tulare Lake. The largest areas lie in the Tulare and Visalia regions and to the east. Cottonwood Creek is bordered by a body several square miles in extent, around and west of Rayo. Most of the group merges with associated recent alluvial soils, but is more sharply defined along the contact with the old valley-filling soils.

Topography and drainage.—The surface is sloping or flat, depending largely upon location on the upper or lower valley slopes. The surface in detail is slightly diversified by ridges and intervening depressed strips. For this reason drainage conditions frequently vary, and there are often important agricultural differences between the soil on the ridges and that in the swales, although the range in elevation may be no more than 2 or 3 feet. Drainage is good over most of the group on the higher valley slopes, although small parts are occasionally overflowed. The drainage becomes poorer toward the valley trough, where the swales are often affected by a permanently high water table and by large accumulations of alkali. Even near the valley trough, however, the ridges may consist of good agricultural land.

Utilization.—The group has a high average value, although some important areas are covered by salt grass and utilized only for pasture. The soils produce heavy yields of prunes, peaches, alfalfa, grapes, and various other crops, and often constitute the main soils in intensively developed localities. The choice of crops for the group is governed by several factors, chief among which are frost conditions, position of the water table, the occurrence of alkali, and the supply of irrigation water. Citrus fruits are not generally grown, but some plantings have been made near Rayo. Here also are many vineyards. Many of the fruits are grown without irrigation where the water table lies comparatively near the surface.

Chino Series.

The soils of the Chino series typically are dark gray to black, but include brownish-gray variations. They are derived from alluvial deposits coming from rocks similar to those supplying the materials giving the Hanford soils. The surface soils are friable and micaceous and are easily tilled. The subsoils are in many places lighter colored than the surface soils and typically contain concentrations of lime

and occasional compacted layers. The surface is sloping to flat. Drainage usually is defective.

The series is represented in this survey by one mixed group, the Chino and Foster loams, undifferentiated.

CHINO AND FOSTER LOAMS, UNDIFFERENTIATED.

The group Chino and Foster loams, undifferentiated, consists mainly of the Chino loam and the Foster loam.

Description.—The soil of the Chino loam is a dark brownish gray to dark-gray friable loam, free from gravel or gritty material and rather high in organic matter. The soil is underlain at depths ranging from 12 to 36 inches by a lighter colored grayish or brownish subsoil, which typically contains lime varying in quantity and character from slight concentrations to thin fragmentary or partially cemented layers that make the subsoil less permeable than is usual for recent alluvial soils.

The Foster loam typically is a dark-brown or dark grayish brown, friable, micaceous loam, usually free from gravel. The type is rather high in organic matter. The soil occasionally extends to a depth of 4 or even 6 feet or more, but as a rule it is underlain at 12 to 36 inches by a brown or grayish-brown subsoil which is similar to the surface soil in texture in some cases but usually consists of stratified layers. Gravelly or sandy layers occasionally make up the subsoil, but are less prominent than in the Foster sandy loams. Concentrations of lime or compact and altered strata in the subsoil are not typical, but may occur along the contact with the Chino loam.

The group includes streaks or patches of brown soil, generally consisting of overwash of Hanford material. Deposits of lighter or heavier texture are also included and may constitute more than 50 per cent of the surface in some places. The soils in areas affected with alkali are more puddled and of lighter color than elsewhere. Areas of the group in the former bottom of Tulare Lake have a peculiar light grayish color, and both soil and subsoil seem high in lime. Both the soil and subsoil in such places carry shells. The group is often arbitrarily separated from the Merced loams where the two groups merge, but the latter in its typical occurrence includes soils of more altered and calcareous nature than the Chino and Foster loams.

Location.—The most extensive occurrence of this group of soils is in the region between Tulare and Tulare Lake, where it occupies a number of large and some smaller areas. Other areas are mapped north and southeast of Visalia and southeast of Tulare. These areas are slightly lower lying and more nearly flat.

Topography and drainage.—The surface of the soils in this group ranges from gently sloping on the alluvial fans to almost flat in the

lake bottom, with slight irregularities in the form of low ridges and swales. Shallow drainage ways traversing the type occasionally overflow. Drainage is good in some of the more important areas, but some of the lower, swalelike or flat areas are inadequately drained. In such places accumulations of alkali have taken place, the quantities ranging from slight concentrations to concentrations sufficient to render the soils unfit for agriculture until reclaimed.

Utilization.—In the more favorably situated areas these soils are as valuable for the production of fruits and intensive crops as the average of the Foster sandy loams, and in places they are used for the same crops as the Foster sandy loams or adjacent types of the Hanford series. Alfalfa is one of the most important crops in the large areas, such as the one west of Tulare, and the dairying industry is highly developed. Grain and grain hay give good yields. Moist areas are capable of producing many crops without irrigation, but are more often affected with alkali than the better-drained soils. These require irrigation for best results. Water is supplied both by gravity canals and by pumping from underground sources. The alkali areas are used for pasture, often in connection with the dairy industry.

Sacramento Series.

The soils of the Sacramento series are derived from recent alluvium generally deposited in basinlike areas. The materials have been washed from many different kinds of rocks. The soils are dark gray to black or drab, with locally a slightly brownish cast. The content of organic matter is high and the soils are generally friable and retentive of moisture. The subsoils may resemble the surface soils in color and texture or may consist of variable, partly stratified deposits of gray, brownish-gray, or mottled colors. In this survey the lime content of both soil and subsoil is high and usually well distributed through the entire soil column. The substratum either resembles the subsoil or is more mottled and of lighter color. Some of the Sacramento soils, as mapped in this survey, are of lake-laid origin. The surface is smooth and uniform and nearly level, drainage is poor, except where the land is protected from overflow by levees. No alkali is present except in the higher marginal areas bordering the upland soils. There is little tree or brush growth, but a growth of tule is encountered in places.

The group Sacramento clay loams and the single type, Sacramento clay, are mapped in this survey.

SACRAMENTO CLAY LOAMS.

The group Sacramento clay loams includes two types, the Sacramento clay loam and Sacramento silty clay loam, of which the former is much the more extensive.

Description.—The Sacramento clay loam, to depths of 12 to 18 inches, consists of a dark-gray, brownish-gray, or black, heavy-textured, nonmicaceous clay loam. It is high in lime and organic matter and generally friable, though likely to puddle unless tilled under proper moisture conditions. With the exception of large quantities of mussel shells, no coarse material is present. A compact layer several inches in thickness frequently is encountered within the surface 12 inches. The subsoil to a depth of 6 feet or more closely resembles the surface soil in texture, but it is slightly lighter in color as a rule and shows tendencies toward stratification. It is high in lime, but with few apparent concentrations. Where aeration and drainage are poor the subsoil is slightly mottled with brown iron stains. Pronounced mottled drab layers of heavy texture prevail below a depth of 6 feet.

The Sacramento silty clay loam closely resembles the clay loam in all features except texture, which is more silty. It occurs as small areas and in gradational zones between the Sacramento clay loam and other types. Small areas of lighter textured soils of the Foster and Hanford series are included, largely in zones of transition.

The soils of this group in general have a smooth, uniform surface, though in some areas small depressions occur locally.

Location.—The group covers 28.8 square miles. It occurs as a rather narrow belt partly encircling Lake Tulare on the north and east and extending a short distance up Kings River. It occupies a part of the outer portion of the old lake bottom and usually occurs between the Sacramento clay and higher lying, lighter textured types. Much of it has been reclaimed and is protected by levees.

Topography and drainage.—The group has a smooth, uniform surface with practically no variation, except occasional minor sloughs. The gradient is so slight that surface waters are removed very slowly, and usually by percolation through the soil and subsoil or by evaporation. The group is practically free from alkali; only marginal areas and local spots are affected. The uniform surface and gentle slope are favorable for irrigation and tillage, little or no leveling being necessary.

Utilization.—The group is devoted almost entirely to the production of grain and alfalfa, the latter crop being grown on the better drained parts. Yields of both crops are good, but alfalfa is short-lived owing to the poor subdrainage. Both crops require irrigation for best results. Water is supplied mainly by pumping from the lake and wells.

The custom in grain culture is to lay the land off in large checks and flood the surface after harvest with enough water to saturate the soil to a depth of several feet. As soon as the surface is sufficiently

dry the land is plowed, usually with a large tractor, and seeded to grain. This practice is harmful to some soils, but the large quantities of lime and organic matter in this group tend to maintain it in a friable, mealy condition. In years of normal rainfall the grain is matured without additional watering, but where the crop is sown late in the fall and the following spring is unusually dry, additional irrigation is sometimes given.

Practically all the group is tilled, and sections suited to alfalfa are developing into dairy centers. Artesian water is generally available at relatively shallow depths. The price of land values varies somewhat, depending upon location and development. It usually brings more than $100 an acre.

SACRAMENTO CLAY.

Description.—The Sacramento clay is dark-gray, drab, or black clay, sticky and plastic when wet, but ordinarily of friable, granular structure, tending toward adobe. The soil is nonmicaceous, free from gravel or coarse sand. It contains much lime and organic matter. Mussel shells are present in varying quantities. A somewhat compact layer several inches in thickness often occurs near the surface.

There is no definite line of demarcation between the soil and subsoil, but below 12 or 18 inches the material is slightly lighter colored, with a tendency toward mottling and stratification. It is also somewhat higher in lime than the surface soil, though the lime is uniformly distributed, conspicuous concentrations being absent. The substratum is more mottled than the subsoil. The type, as a whole, is very uniform in texture and color, slight variations occurring only where streams enter the lake or near adjoining higher lying types.

Location.—The type is of only moderate extent. It occurs in several bodies around the margin of Lake Tulare and in one area west of Stratford. It is the lowest lying soil of the Tulare Lake basin and probably covers the entire bottom of the present lake, all of which has been exposed and farmed at some time.

Topography and drainage.—The type has a smooth, uniform, nearly flat surface favorable to tillage and irrigation. Surface drainage is slow, owing to the slight slope, and underdrainage is poorly established because of the high water table and the heavy texture of the subsoil. The type has been reclaimed and is protected from overflow by a series of levees. No alkali is present.

Utilization.—The Sacramento clay is under cultivation and is utilized almost entirely for grain production. High yields are ob-

tained and the same methods of irrigation and tillage are practiced as on the Sacramento clay loams. A small part of the type adjoining higher lying soils has better drainage and is used in the production of alfalfa. Yields are high, but the crop is short-lived, owing to inadequate subdrainage.

SOILS FROM WIND-LAID MATERIAL.

Oakley Series.

The soils of the Oakley series consist of wind-laid deposits, derived in this area largely from the sandy material of the Fresno and Madera series with small quantities blown from the beds of intermittent streams. The surface soils are brown or grayish brown in color and contain relatively large quantities of fine material, giving them a loamy character. The content of organic matter is low, but the soils are nevertheless retentive of moisture. The subsoil usually resembles the surface soil in color and texture. It may be lighter brown, and in places is underlain by heavier textured old valley-filling soils at a depth of 4 feet or more. The surface is undulating or slightly rolling, and drainage is good except in some small depressions. The soil drifts considerably in exposed surfaces.

The series is represented in this survey by two groups, the Oakley and Madera sands, undifferentiated, and the Oakley and Fresno sands, undifferentiated.

OAKLEY AND MADERA SANDS, UNDIFFERENTIATED.

The group Oakley and Madera sands, undifferentiated, includes the Oakley sand and the Madera sand. The former comprises more than 75 per cent of the total area of the group.

Description.—The Oakley sand is a brown, uniform, open-structured sand, extending without a distinct subsoil to depths of more than 6 feet. It frequently contains a small percentage of mica, but is free from gravel. Slight variations in the cross section are common. The type sometimes occurs as a surface covering several feet deep over heavier-textured soils of other series, and includes small bodies of coarse sand, loamy sand, and sandy loam. The subsoil in typical areas is similar to the surface material in color and texture, but in places the color below a depth of 3 or 4 feet is slightly reddish brown. The soil is easily tilled. It is generally low in content of organic matter, but contains considerable fine material and is retentive of moisture and very desirable for agriculture.

The Madera sand consists of 2 to 5 feet of brown or grayish-brown open-structured loamy sand and, locally, small quantities of coarse sand and fine gravel. The color is intensified or may be slightly

reddish brown when the soil is moist. Some mica is present in places, the quantity depending upon the activity of small streams and the proximity of light-textured Hanford soils. The soil is low in organic matter, but is easily tilled and quite retentive of moisture. Where typically developed the subsoil is either a light sandy loam or a loam of brown or reddish-brown color and is underlain by a hardpan generally at depths of slightly less than 6 feet. Parts of the type nearest soils of the San Joaquin series frequently have more pronounced subsoils and a shallower hardpan, which is frequently encountered at 3 to 4 feet below the surface. The hardpan and lower substratum are typical of the Madera series. The subsoil has a local tendency toward stratification. The type is quite variable, owing to its occurrence in small areas, and it includes patches of coarse sand and sandy loam of the series.

Location.—This group covers about 39 square miles. It occurs on irregular, low, rounded ridges, in flats, and in smooth, gently sloping bodies. The most extensive areas lie in the region south and southeast of Clovis and around Fresno, and less extensive areas near Centerville, southeast of Campbell Mountain, and at a few other places. The group is confined to the east side of the valley in this survey and occurs entirely on the valley plains.

Topography and drainage.—The surface of the Madera sand is uniform, smooth, and gently sloping, with few irregularities that interfere with irrigation. The Oakley sand is undulating, irregular, and dunelike in places and includes rounded ridges having a northeast to southwest trend. The mounds and ridges are several feet above the general level of the plain in many places, and while they have a smooth surface they are difficult to irrigate. The group includes a number of depressions, some of which are inundated and support a growth of tule. These soils absorb moisture readily, and there is practically no surface run-off. The underdrainage is also well established, and there is little damage from a water-logged condition or from alkali. The Madera sand is a modified alluvial soil and the Oakley type consists of wind-blown material derived principally from the light-textured types of the Madera and Fresno series.

Utilization.—The soils of this group are among the most intensively cultivated in the area. Practically all their area is under cultivation, fruits, alfalfa, sweet potatoes, and early truck crops being the leading products. Good yields of grapes and some other crops are obtained under dry-farming methods in favorable places with proper care, but yields are increased by irrigation. Very little commercial fertilizer is applied in growing these crops, but manure and cover crops are used to some extent, giving good results. The price of land varies greatly, and depends upon the location, state of development, uniformity of the soil, and possibility of irrigation.

OAKLEY AND FRESNO SANDS, UNDIFFERENTIATED.

The Oakley and Fresno sands undifferentiated include the Oakley sand and the Fresno sand, of which the former predominates.

Description.—The Oakley sand consists of a brown or grayish-brown, open-structured loamy sand, usually of uniform texture to a depth of 6 feet or more. The soil contains some mica, is somewhat browner than the Fresno sand, and does not show any tendency toward stratification, except where it occurs as a surface covering overlying other soils. The soil is low in content of organic matter, is easily tilled, and does not have hardpan or noticeable compact layers in the subsoil. It is generally uniform, but some small depressions or flats among the ridges include small areas of sandy loam or fine sandy loam.

The Fresno sand, as included in this group, consists rather of a brown phase of that type than of the typical soil as recognized elsewhere. It is a brown or grayish-brown, open-structured sand, usually carrying small quantities of mica. The soil varies slightly in color and is somewhat more compact in moist areas than elsewhere. In many places little variation in the soil section occurs to depths of 6 feet or more, but typically the subsoil at a depth of several feet becomes browner, more compact, and slightly heavier textured, and rests upon the gray or grayish-brown hardpan typical of the Fresno series. The subsoil, hardpan, and underlying substrata are intermittently stratified. Lime is conspicuous in the hardpan and immediately above or below it, but the content is usually lower than in the heavier textured types. The hardpan is variable and ranges from an aggregation of lime casts or nodules to thin, intermittent lenses. It may locally be absent. Where it lies well below the surface it sometimes has a beneficial effect in checking the loss of soil moisture by percolation. The type is low in organic matter and is easily tilled. It is very retentive of moisture, and there is little run-off. The soil to a depth of many feet, except for the hardpan, is permeable, and crops root deeply. Where plowed and unprotected by crops the soil is easily disturbed by the wind, and drifting sand occasionally damages young plants. A compact layer is sometimes encountered several inches below the surface. Numerous loamy spots with a nearly level surface are included with this soil. These constitute in the aggregate an important part of the type. It also includes a few strips of coarse sand, which are porous and droughty, and some low spots of sandy loam and strips of fine sand.

Location.—The soils of this group are extensive and among the most important and highly developed soils of the area. They are confined to the east side of the valley trough and are prominent in the general region south of Fresno, being the dominant type in places,

as west of Selma and Fowler and around Caruthers. They occupy valley slopes above the channels of the larger streams.

Topography and drainage.—The surface of the Fresno sand is nearly level to gently sloping, and there are few irregularities to interfere with irrigation or tillage. The Oakley sand has an uneven, slightly rolling, or undulating surface and shows the effects of wind action. Both soils usually have good surface drainage and subdrainage, and both are retentive of moisture. Alkali is present only in those areas where the soils occur as a thin covering over older and heavier textured soils. The surface of the Oakley sand is often so uneven that irrigation is difficult, but otherwise the type is well adapted to farming. Winding streamways, numerous circular depressions, and segments of old stream channels are common. Some of the deeper depressions are partly filled with water during the irrigating season and often support a growth of tule.

Utilization.—This group is nearly all tilled to intensive crops, and produces an important part of the fruit crop of the area. Grapes and peaches are among the leading products, and are grown both with and without irrigation. (Pl. III, figs. 1 and 2.) Besides these fruits, apricots, nectarines, figs, and olives are grown to a small extent, the last two frequently being grown as border trees. Egyptian corn, beans, melons, and sweet potatoes are also produced in places with little or no irrigation. Alfalfa requires irrigation for best results. The soil warms readily and matures crops early. Hoed crops are often grown in young orchards, where the water supply is abundant. The soils are very easily tilled and a mulch is maintained without difficulty. No definite crop rotation is practiced, but changes in cropping are frequently made. Special methods of irrigation are generally necessary in order to minimize the loss of water by percolation.

Most of the soils of this group are well located with reference to roads and shipping points. Water is supplied both by gravity canals and by pumping from underground sources.

MISCELLANEOUS MATERIAL.

ROUGH STONY LAND.

Description.—Rough stony land typically includes soils which are too stony, rough, and steep for agriculture. It is differentiated from Rough broken land by its stony character. As mapped in this survey it consists largely of shallow, excessively stony soils, ranging in texture from a sandy loam or coarse sandy loam to a heavy clay adobe, which under different surface conditions would be classed with such series as the Olympic and Holland. Rock outcrop and loose surface rock are abundant, both granitic and quartz-free igneous rocks being represented. The soil material is normally shallow and droughty,

being deepest where the granitic rocks prevail. The type includes areas capable of tillage.

The bodies in the western part of the area, such as those in the Kettleman Hills, are rough and unsuitable for tillage, but are not very stony. Occasional rock outcrop is present, but the underlying sedimentary rocks quickly disintegrate. These bodies constitute Rough broken land, but are included with the Rough stony land because of their small extent.

Utilization.—The Rough stony land is untilled. Its principal use is for pasture. The growth of grass on the west side of the valley is sparse and on the east side varies with the depth and texture of the soil.

IRRIGATION.

Owing to the low rainfall, its irregular distribution, and the high rate of evaporation in the growing season, irrigation is necessary for the best results with most crops. Even grain and grain hay can not be grown successfully over a part of the area under dry-farming methods. Irrigation is especially desirable for most of the fruits, for crops grown on shallow soils, or those low in organic matter or of unfavorable structure, and where the drainage is excessive and the exposure unfavorable. Furthermore, a large number of intensive crops can not be matured properly without irrigation, and the high price of land in many cases renders dry-farmed crops of relatively low value unprofitable.

Irrigation has been practiced extensively for many years, but has been confined almost entirely to the east side of the valley, where there are more available water supplies. The low lands along the larger streams were irrigated first, because of the ease of obtaining water, and success with irrigation of these soils led to the introduction of more intensively cultivated and more profitable crops. The construction of canals to carry water to large areas of the higher-lying plains followed, and rapid development and increasing land values accompanied greater returns from the soil. Additional areas have been brought under irrigation, until at present the supply of gravity water is nearly all apportioned and large quantities of underground water are utilized by pumping, to supplement that supplied by the canals. Supplies from the latter source are still being drawn upon freely in many new developments. Small supplies of artesian water are obtained in the lowlands near the trough of the valley, but this water is utilized mainly for watering cattle, for home use, and for irrigating gardens. Some water is obtained by pumping from sloughs and relatively large quantities are either pumped or drawn directly from Tulare Lake in favorable years for the lowlands immediately bordering it.

The San Joaquin River with a mean annual discharge of 1,944,000 acre-feet per year, the Kings River with 1,940,000 acre-feet, the Kaweah with 506,000 acre-feet, and the Tule with 137,000 acre-feet[1] are the main sources of gravity water for the east side of the valley within this survey. The water of the San Joaquin River is largely appropriated for use outside the area, and Kings River is by far the most important source of gravity water within this survey. Los Gatos, Waltham, Cantua, and Panoche Creeks are the principal streams entering the area from the west. They are small and intermittent in character and are not reliable sources of supply. Little has been done in reservoir construction for the storage of flood waters, but such supplies are capable of increasing the acreage of irrigated lands. The supply of water from Tulare Lake is fluctuating. The lake now covers about 100,000 acres, being largely confined within levees. It became dry in 1905 and its bed was farmed. This seldom occurs, and the lake usually supplies ample water for irrigation of bordering lands. A little less than 1,000,000 acres of land are now under irrigation in the area and this is being added to yearly by new irrigation projects. The water is predominantly of good quality for irrigation purposes, but that from some of the wells on the west side of the valley or along the valley trough contains relatively large, though varying, quantities of soluble material.

Most of the canals supplying gravity water have been constructed by water companies or by the formation of irrigation districts. Joint ownership of wells and pumping plants exists in places where underground supplies are used, but individual ownership is the rule. As a rule pumped water is much more expensive than gravity water, its cost depending upon the depth of the wells, the amount of water obtained, the type of engine, and kind of power used. The wells are deepest along the more elevated valley slopes, and are often relatively shallow on the lower slopes near the valley trough. Some of the wells on the west side of the valley are many hundreds of feet deep.

Methods of applying water to the land vary greatly with the crops grown, the type of soil, slope, and head of water used. The check and border methods and movable pipe lines prevail for the irrigation of alfalfa. Citrus fruits are irrigated by the furrow method, and this and the basin system are used for deciduous fruits and vines. The check system is used for rice, for which large quantities of water are required. In growing this crop it is necessary to prepare the land carefully to control water conditions. The water of Tulare Lake is used principally for irrigating grain land in preparing it for tillage and in supplying moisture for the growth of the crop. The water is either pumped over the levees or diverted through

[1] U. S. Geol. Survey Water Supply Paper No. 398, Ground Water in San Joaquin Valley, Cal., 1916; No. 299. Stream Measurements in San Joaquin River Basin, 1912; Office of Expt. Sta., U. S. Dept. of Agr., Bul. No. 254, Irrigation Resources of California and their Utilization, 1913.

head gates and allowed to spread over the land to a depth of several inches. After thoroughly wetting the soil it is turned off. The land is then plowed and sowed to grain. In unusually dry years a second irrigation is sometimes given in the spring.

Further extension of irrigation will probably involve the storage of flood waters, the greater use of underground supplies, and the conservation of all water supplies by a more efficient use of water and better tillage methods. More economic use of water will tend to keep the water table of low-lying areas at a safe depth, reduce damage from seepage and accumulations of alkali, and enable the extension of irrigation to additional areas. The extension of irrigation would also be facilitated by utilizing the moist phases of the light-textured soils for intensive crops which do not require the addition of water for profitable returns. This practice is already quite extensive. Apparently it will be difficult to supply water to vast areas of good soil on the west side of the valley, as the run-off from the Coast Range and underground supplies seem inadequate. Some system of drawing water from the trough of the valley or from storage on the east side may be developed. In general, the water supply seems inadequate to provide irrigation for the total land area of the survey, and the most efficient use possible of the water should be made.

ALKALI.

The central part of the area contains a large acreage of alkali land similar in many ways to the alkali-affected regions in Madera, Merced, and Stanislaus Counties to the north. There is a belt, averaging several miles in width, of relatively alkali-free soils extending along the lowest part of the valley from Tulare Lake on the south almost to Mendota on the north. This strip is bordered on the west by a continuous body of alkali soils varying in width from less than 1 mile to 6 or 7 miles, which includes practically all the affected lands of the west side of the valley. The alkali areas on the east side of the valley are much greater in total extent than those on the west side and include many small areas detached from the main alkali areas. One of the larger areas of the east side begins a short distance south of Fresno, and gradually broadening to the west, extends to the valley trough, a distance of 20 to 30 miles. This area is very irregular in outline, and is indented around its margins by protruding points of alkali-free soils. Near the valley trough a lobe of the main body extends eastward, passing south of Caruthers and north of Laton. A prominent alkali area lies around Traver and extends east, west, and south for many miles, with strips reaching from the main body into alkali-free areas. Another area of rather uniform alkali land lies west of Tipton. There are several other large areas of alkali, and in addition some important sections in

which the soils, while not uniformly affected, are spotted or streaked with alkali. In the Visalia, Tulare, and Farmersville regions, for instance, some of the best soils show this condition, the proportion of their area affected being sometimes small and sometimes large. The same conditions prevail in Kings County, the alkali areas ranging from small bodies, as north and west of Hanford, to those of large size, as south and southwest of Hanford. In general alkali conditions are more pronounced in regions of restricted drainage, as on flats or in areas with only a gentle slope toward the valley trough. Aside from local spots the higher valley slopes are free from alkali.

The term "alkali" as applied to soils refers to various soluble salts which have accumulated in sufficient quantity to affect the agricultural value of the soils. The alkali in the soils of this area, as in most other regions, has been deposited largely through excessive surface evaporation of soil moisture, and poor drainage has nearly always been a factor of primary importance in this process. The greater part of the large alkali areas and of many of the smaller ones accumulated enough soluble salts under natural conditions before settlement of the region to define their character, but extensive irrigation of the higher-lying adjacent valley slopes has been accompanied by a rise in ground-water levels in associated lower-lying belts, and this has been favorable to the extension of the original alkali areas and the development of many new ones, as in the Fresno region and the Traver and other districts. In many cases the accumulation of alkali has caused the abandonment of intensively cultivated land, but such abandoned land constitutes a small part of the total area of alkali soils.

The principal alkali areas are shown on the soil map which accompanies this report. A former report on the Fresno area[1] is accompanied by two alkali maps, one of which shows the total salts in the soil, in several grades of concentration, and the other the distribution of black alkali. The outlines of the alkali areas were transferred from the former map to the soil map accompanying this report, and alkali boundaries for the remainder of the area were determined in the present survey. In this survey no attempt is made to differentiate between different degrees of concentration, and in consequence the areas of alkali soils shown include areas affected only in spots containing low percentages of salt and those carrying such high percentages that the growth of all kinds of crops is prohibited. The quantity of alkali present usually is indicated by the character of the native vegetation and by surface accumulations. The least affected areas usually have occasional barren spots and a heavy growth of salt grass or, in abandoned fields, Bermuda grass. Soils with higher percentages of salts have more frequent and extensive

[1] Soil Survey of the Fresno Area, Cal., Field Operations of the Bureau of Soils, 1912.

barren spots with a patchy growth of different kinds of alkali plants, and the worst affected areas are often barren of plant growth over more than 50 per cent of their surface. Boundaries outlining alkali areas are sometimes more or less arbitrary; in other cases they are definite. In addition the character of the present survey precludes detailed separations, and for these reasons the alkali areas often include small bodies of good agricultural soil and the alkali-free areas sometimes locally include badly affected spots.

Many analyses have been made to determine the various salts making up the alkali and their relative amounts, and the results of some such analyses are given in the report on the Fresno area, to which reference has already been made. The most important components seem to be chloride, sulphate, bicarbonate, and carbonate of sodium. Black alkali or sodium carbonate is often prominent in the alkali lands of the east side of the valley, but apparently absent on the west side, except locally, owing to the calcium sulphate or gypsum usually carried by the rocks giving rise to the soils. The black alkali is commonly believed to be more injurious than the other salts, which are known by the general term "white alkali."

Alkali soils are often in poor physical condition; the main areas which have been affected by alkali for long periods have attained a puddled structure, unfavorable for the absorption and retention of water. They have a characteristic grayish color. Some bodies have light-colored hardpans which in places contain alkali.

Mention is made in the descriptions of the individual soil types or groups of soils of prevailing alkali conditions. The residual soils and the old valley-filling soils of the higher valley slopes are usually free from alkali, but a number of the recent alluvial soils and some of the old valley-filling types are affected where drainage is poor, or where earlier drainage conditions were favorable for alkali accumulation and the salts have not been leached away. Soils of the Fresno and Hanford series are extensively represented in some of the more pronounced alkali areas, various types of the former series constituting a large part of the affected sections southwest of Fresno, around Traver, west of Tipton, and elsewhere. Types of the Hanford series often predominate in alkali areas of the Hanford, Visalia, and Tulare regions, relatively low bodies of this series often being affected. The Foster, Merced, and Chino series are interruptedly affected and it is difficult to outline the alkali boundaries where very slight concentrations alternate with patches of greater alkali content or with alkali-free areas. The alkali area on the west side of the valley is confined largely to the flattened extensions of alluvial fans occupied by soils of the Panoche series (Pl. II, fig. 2), and it is possible that subsoils of additional areas of that series bear alkali, extending the alkali boundary farther westward in some instances. The Madera series

usually is free from alkali, but some small areas in this survey are affected, as near Seville and south of Exeter.

The vertical distribution of the alkali in the soil is subject to considerable variation, but maximum concentrations occur much more frequently in the surface foot, especially in areas with a shallow water table or areas of soils having a uniformly light or medium texture throughout the 6-foot section. Soils of relatively heavy texture show fewer surface indications of alkali than light-textured soils bearing similar quantities. Similar percentages are also more harmful in the latter. Some important alkali areas, such as many of those in Kings County, have nearly all the alkali in the surface few inches, and support a heavy growth of salt grass. In many such instances the total alkali content is lower and the general value of the soil higher than might be inferred from field appearances. While alkali areas are usually of lower elevation than adjacent alkali-free soils, this is not always true, as in some of the bodies in the region west of Tulare the older deposits have accumulated alkali and occur as remnants surrounded by lower, more recent alkali-free deposits which are often overflowed.

The utilization of alkali lands is dependent upon several factors, chief among which is the percentage and kind of alkali present, although other considerations, such as texture of the soil, location, and position of the water table also are important. The main alkali areas of this survey are for the most part untilled and used only for pasture, a small part, not more than 25 per cent of the total, being farmed either regularly or intermittently. Soils bearing low percentages, or those affected by spots or streaks, are often farmed in conjunction with associated alkali-free soils, giving lower yields of grain, alfalfa, sorghum, and other field crops. Farms lying in regions streaked with alkali are often sharply divided, a part being capable of producing fruits and other intensive crops and the remainder affected by alkali and valueless except for pasture. The high water table and more exposed positions as regards frost accompanying the low-lying alkali regions are also factors detrimental to fruit production in such places.

The reclamation of alkali lands is receiving increased attention[1] and experiments have been conducted on several small tracts within the area. Local efforts by farmers have been more or less successful, depending largely upon the character of the land and the methods used. Careful leveling of the land and liberal irrigation have sometimes been sufficient to permit the cultivation of shallow-rooted crops, and considerable areas have been at least temporarily improved in this manner. No comprehensive effort has yet been made toward

[1] See Buls. Nos. 21, 34, 35, and 42, Bureau of Soils, and Buls. Nos. 83, 128, and 273, Cal. Agr. Expt. Sta.

reclamation, although many plans have been considered. The success of reclamation is dependent largely upon outlet for drainage waters and an abundant supply of water for flooding and leaching the soil. A large part of the alkali lands lie in low areas without ready drainage outlets, and water for reclamation purposes often is not readily available at a low cost, so that a comprehensive drainage enterprise or perhaps a series of drainage projects, wherein an outlet for drainage and water can be obtained at a minimum cost, apparently is required. A lowering of the water table is imperative in permanent reclamation of most of the alkali lands and considerable expense and effort will still be necessary to remove the alkali and improve the structural condition of the soils. Soils having shallow hardpan and high concentration of alkali are difficult to reclaim, even after drainage. Those bearing low percentages of alkali and without hardpan are easier to handle and may even be improved somewhat if the water table is merely lowered to below 3 feet. Liberal applications of gypsum would no doubt benefit the latter class of soils if it appears that black alkali is a prominent constituent. Lands under which the water table is shallow and on the surface of which slight alkali traces are beginning to appear should not be allowed to become packed, but should be kept mulched to reduce surface evaporation.

SUMMARY.

The survey covers approximately the central third of the San Joaquin Valley and embraces the most thickly settled portions of Fresno, Tulare, and Kings Counties, one of the most important agricultural regions of the State. It lies near the center of the State, its east and west boundaries extending in general northwest-southeast direction along the lower foothill slopes of the Sierra Nevada and Coast Range Mountains. The total area of the survey is 4,448 square miles, or 2,846,720 acres.

The San Joaquin Valley on the south, together with the Sacramento Valley on the north, constitute the Great Interior Valley of California. This lowland trough has the same general northwest-southeast direction as the State, is about 500 miles in length, and averages about 40 to 45 miles in width. It is inclosed by mountains except for a break in the Coast Range on its west side, where drainage from the valley enters the Pacific Ocean through San Francisco Bay. The Great Interior Valley is a structural trough formed by the uplift of surrounding mountains, and for long periods it has received soil materials washed from the inclosing uplands. Both older and younger deposits make up the present surface.

The area surveyed resembles the remainder of the Interior Valley in its main physiographic features. Smooth valley slopes, which flatten toward the valley trough and increase in steepness toward

PHOTO FROM UNIV. OF CAL.

FIG. 1.—GENERAL VIEW AT KEARNEY PARK.

Madera sandy loams in foreground; Fresno fine sandy loam, brown phase, in distance. Packing house and drying yard and trays used in curing raisins and drying fruits in foreground.

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FIG. 2.—PANOCHE CLAY LOAMS, 8 MILES WEST OF WHEATVILLE, SHOWING SMOOTH TOPOGRAPHY, BARREN ALKALI SPOTS, AND CHARACTERISTIC VEGETATION.

FIG. 1.—RAISIN VINEYARD ON OAKLEY AND FRESNO SANDS, UNDIFFERENTIATED, NEAR SELMA.

FIG. 2.—PEACH ORCHARD ON OAKLEY AND FRESNO SANDS, UNDIFFERENTIATED, NEAR SELMA.

e mountains prevail. An included narrow belt of mountainous haracter along the margins of the valley, together with small rolling reas and isolated hills constitutes the only variation from the noother topography. The valley trough ranges in elevation from bout 165 feet to about 210 feet where partly filled by alluvium rom lateral streams. Drainage from the upper or southern part f the valley collects in Tulare Lake, the bottom of which lies at an levation of about 180 feet. The east side of the valley has a lower radient and longer slopes than the west side. Along the eastern nargin of the valley elevations range from about 350 to 500 feet, and here is an average fall of about 4 or 5 feet per mile to the valley rough. The recent alluvial fans and fragments of older ones are not often sharply defined in general topography. The western margin of the valley is elevated from 500 to 700 feet and is flanked by steep alluvial fans.

The principal rivers are the San Joaquin, Kings, Kaweah, and Tule, the last three discharging into Tulare Lake in normal years. The west side of the valley has only minor intermittent streams such as Los Gatos, Waltham, Cantua, Little Panoche, and Panoche Creeks. Drainage is good on the upper valley slopes but defective over extensive lower areas, where stagnated surface drainage during the wet season and a high water table at all times prevail.

The population of the area is estimated as about 118,200 in 1910, and of this number three-fourths consist of native-born whites. Fresno is the largest city, Hanford and Visalia being next in size in 1910. There are numerous other towns ranging up to several thousand in population.

Main and branch lines of the Southern Pacific and Atchison, Topeka & Santa Fe Railroads furnish the main rail transportation, and a number of local electric lines are in operation. The thickly settled sections have good rail and highway facilities, but the sparsely settled localities are poorly supplied.

The fruit products are exported from the area for distribution throughout the United States and shipment abroad. The more bulky or perishable products are shipped less distances.

The climate is characterized by a hot, dry summer and a cool, wet winter. Local variations in climatic conditions materially influence the distribution of crops. Precipitation is greatest along the eastern margin of the valley and decreases to the west and to the south. From 8 to 12 inches of rain is the rule in the eastern part of the area and about 4 or 5 inches in the southwestern part. Practically no rain falls from June to September, inclusive. The mean annual temperature at Fresno is 63.2° F., the average for July, the warmest month, is 82°, and for January, the coldest month, 45.4°. Points

farthest from the foothills or at lower elevations are coldest. The absolute minimum temperature at Fresno is 17° F. and the absolute maximum is 115° F. Locally frost conditions are favorable to citrus-fruit production. Fog often occurs during the early part of the day in the winter. Wind movement is moderate, and hail and snow are practically unknown.

The early agriculture was localized along the streams and was subsidiary to stock raising and mining. Dry-farming grain production later extended over the valley plains and encroached upon the cattle ranges. Irrigation accompanied by the culture of highly specialized fruit crops developed slowly at first but rapidly later, and fruit products now dominate the agriculture of the area. In addition to fruit production alfalfa growing, dairying, stock raising, cereal production and other industries are important, often in areas not well suited to fruits because of soil, drainage, climate, or irrigation conditions. Fresno, Tulare, and Kings Counties in 1910 reported crop values totaling $16,525,295, of which more than one-half represented fruit products. The most extensive citrus-fruit region of central and northern California is in this area. Grapes, peaches, figs, prunes, and olives are important products.

The soils of the area differ widely in origin, general character, and value for agriculture. The survey includes some residual mountainous soils, largely underlain on the east side of the valley by igneous rocks and on the west side by sedimentary rocks. The main part of the survey, comprising the valley slopes and floor, consists of wash from the adjacent mountains. The filling processes have been influenced by several factors so that remnants of older valley surfaces and old alluvial fans are prominent, as well as more recent and more symmetrical alluvial fans. Some of the soils of the valley slopes have been accumulated by wind action. The physiographic divisions represented by the mountains, the old alluvial deposits, the young alluvial deposits, and the wind-laid deposits are reflected in the classification of the soils into four main soil provinces designated as (*a*) the residual soils, or those derived in place through the weathering and disintegration of consolidated rocks; (*b*) the old valley-filling and coastal-plain soils, or those derived through the weathering and modification of water-laid deposits of unconsolidated character; (*c*) the recent alluvial soils, or recent stream and lake deposits which have undergone no important changes since deposition, and (*d*) the wind-laid soils, or those formed by wind action. The soils of these main provinces are subdivided into soil series, and the latter into soil types, although it is often necessary to group some of the types in a survey of this character. A total of 39 types or type groups, including the miscellaneous type, Rough stony land, is shown on the accompanying soil map.

The residual soils are inextensive. They are represented by four series, the Kettleman, Arnold, Olympic, and Holland. The first two comprise gray soils, originating from sedimentary rocks. The Holland and the Olympic soils are brown and are derived from two classes of igneous rocks.

The old valley-filling and coastal-plain soils have a large total area. They are classed with eight series, the San Joaquin, Madera, Pleasanton, Antioch, Porterville, Fresno, Merced, and Montezuma. The soils of this province have been modified in various ways since deposition. Some have developed relatively heavy textured subsoils and others calcareous subsoils, and certain series are characterized by distinct hardpans.

The recent alluvial soils are extensive, and are represented by six series, the Panoche, Laguna, Hanford, Foster, Chino, and Sacramento. They include in this survey a few types which have been deposited in flat basins and lakes.

The wind-laid soils are inextensive. They are classed with the Oakley series.

The rainfall is not sufficient for most of the fruits and other intensive crops, and irrigation is extensively practiced, being largely confined to the east side of the valley, owing to the scarcity of water on the west side. Most irrigation is by gravity systems which divert water from the rivers, although important supplies are obtained by pumping from underground sources. Artesian water is locally available, but is relatively unimportant in irrigation. Nearly 1,000,000 acres are under irrigation and the area is being extended. Additional water may be obtained by the storage of flood waters and an increase in the pumped supply. Irrigation practices vary with different soils and crops.

The area contains a considerable area of alkali land in bodies which range in size from a few acres to many square miles. Aside from one large body on the west side of the valley, the alkali lands are largely confined to the poorly drained sections of the east side. Some of the affected soils bear small percentages of salts and are farmed with varying degrees of success, but most carry sufficient quantities to preclude profitable crop production until reclaimed. A large part of the alkali was accumulated under natural conditions, but irrigation has raised the water table under low-lying areas and made conditions favorable for further accumulation, resulting in the enlargement of the original area. Important areas of agriculturally important soils have been abandoned in certain localities. Reclamation by means of drainage and flooding is receiving attention.

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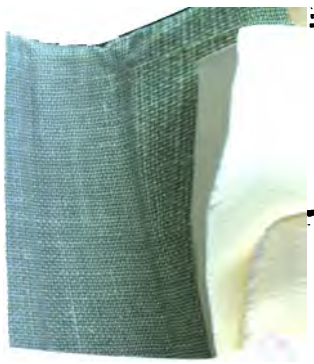

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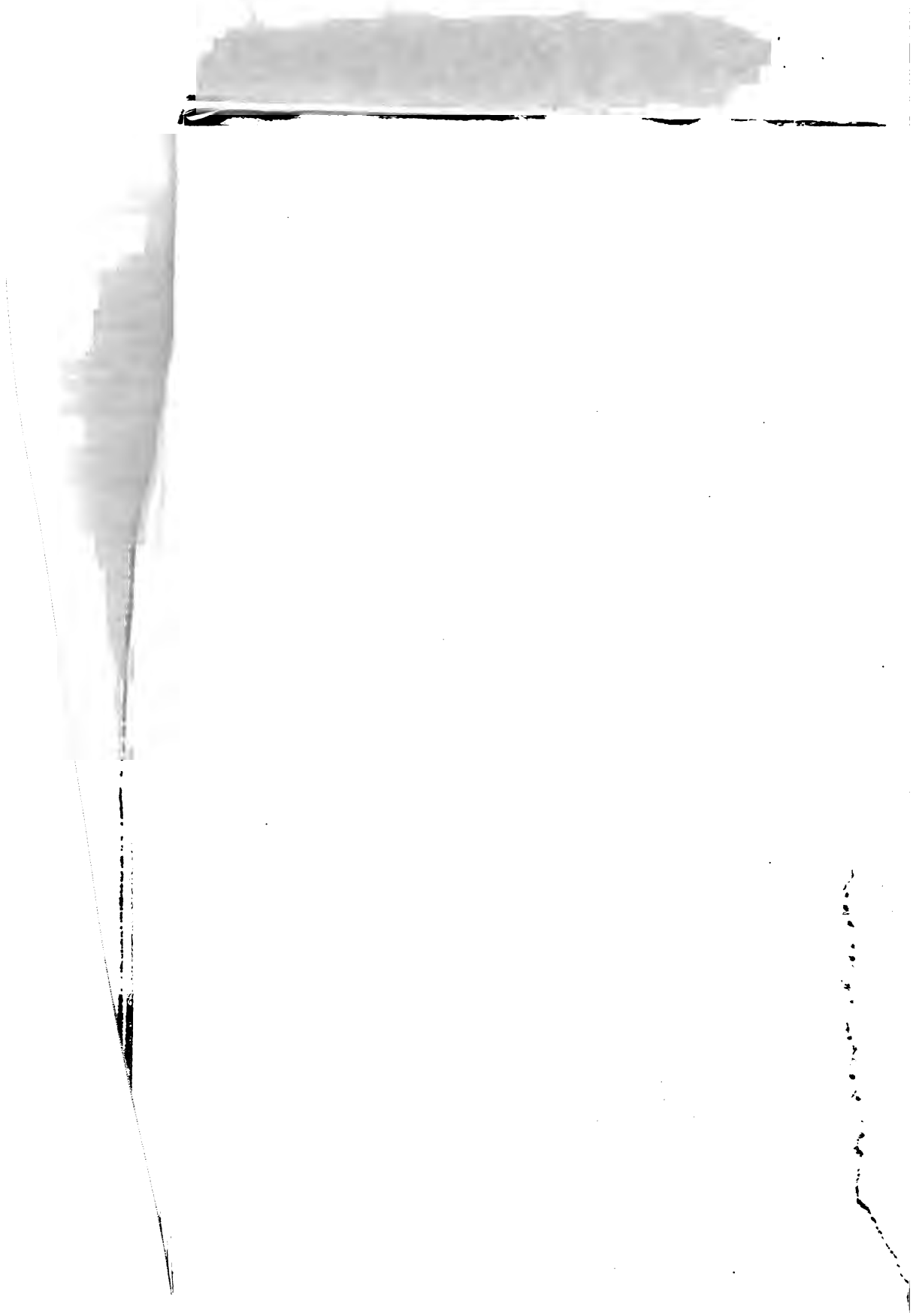

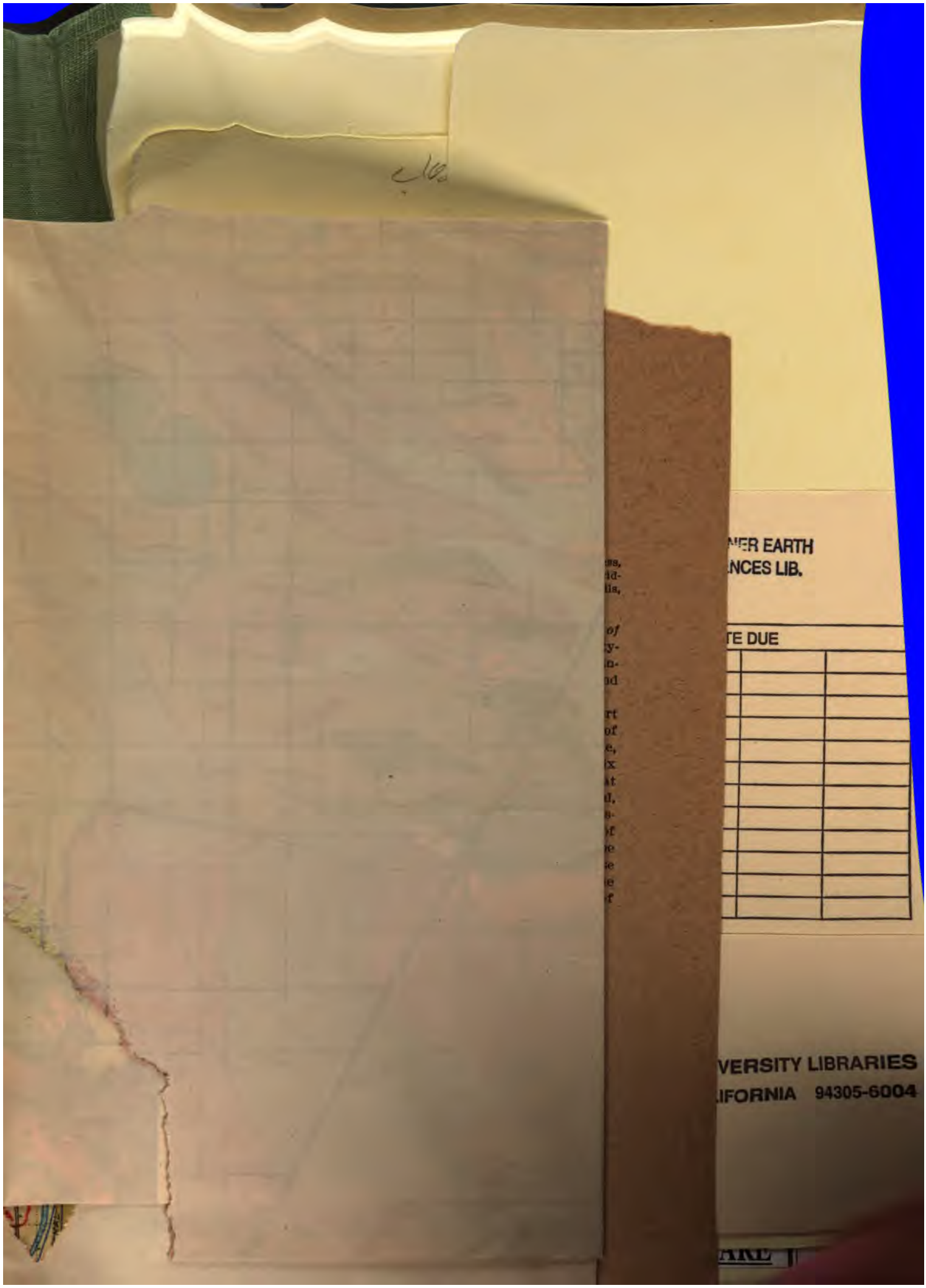
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[PUBLIC RESOLUTION—No. 9.]

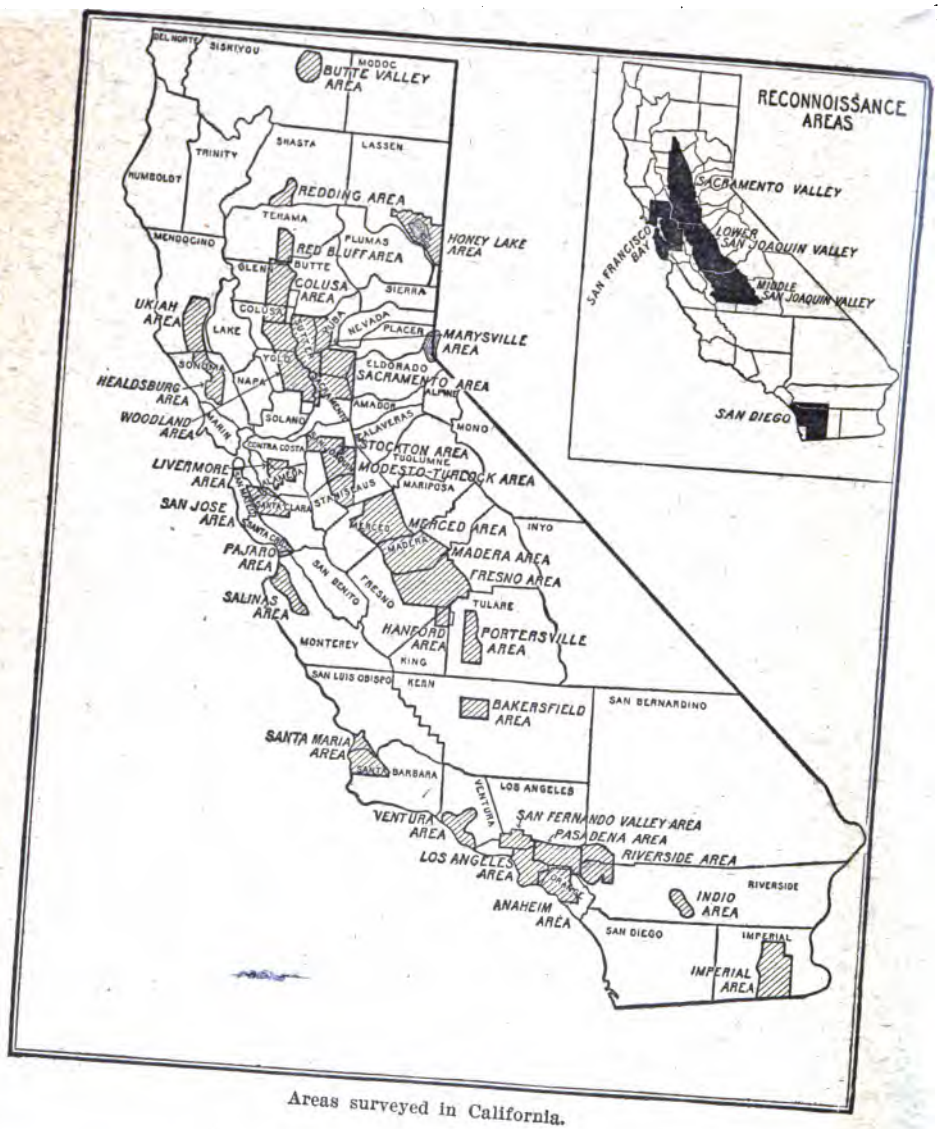
JOINT RESOLUTION Amending public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, "providing for the printing annually of the report on field operations of the Division of Soils, Department of Agriculture."

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, be amended by striking out all after the resolving clause and inserting in lieu thereof the following:

That there shall be printed ten thousand five hundred copies of the report on field operations of the Division of Soils, Department of Agriculture, of which one thousand five hundred copies shall be for the use of the Senate, three thousand copies for the use of the House of Representatives, and six thousand copies for the use of the Department of Agriculture: *Provided,* That in addition to the number of copies above provided for there shall be printed, as soon as the manuscript can be prepared, with the necessary maps and illustrations to accompany it, a report on each area surveyed, in the form of advance sheets, bound in paper covers, of which five hundred copies shall be for the use of each Senator from the State, two thousand copies for the use of each Representative for the congressional district or districts in which the survey is made, and one thousand copies for the use of the Department of Agriculture.

Approved, March 14, 1904.

[On July 1, 1901, the Division of Soils was reorganized as the Bureau of Soils.]



Areas surveyed in California.